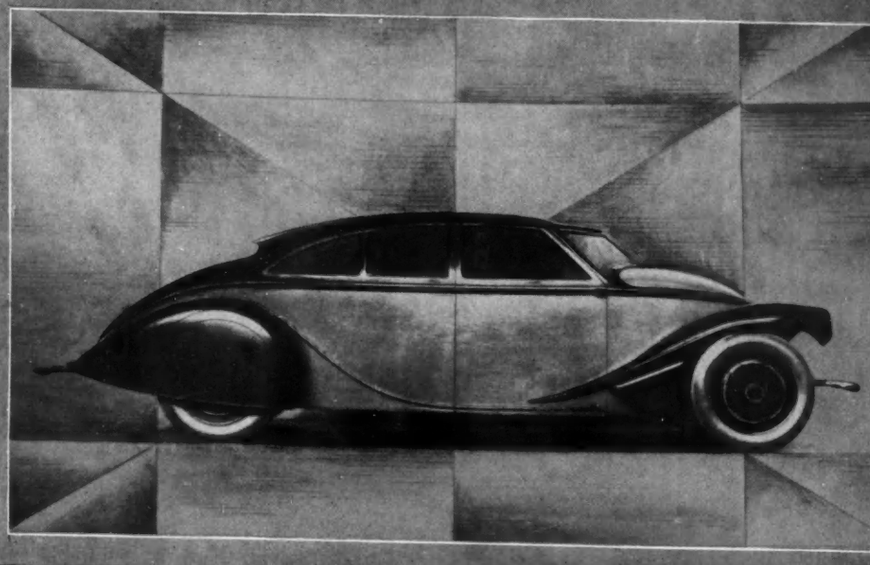
TWO SECTIONS SECTION ONE

JUN 3

S·A·E JOURNAL

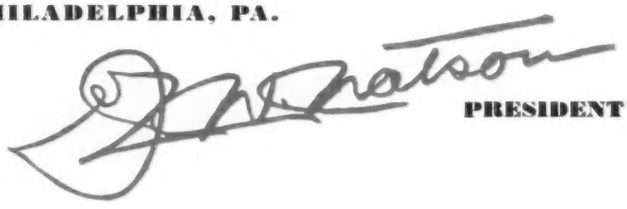


JUNE 1931

The Only Way to Control Anything is to *Nip it in the Bud*

IF you can close in on a man's fist before he gets it started, all he can do is push you. And it would take very little resistance on your part to keep that push down to a comfortable speed. Allow his fist to get under way however and there is then no such thing as *controlling* its movement . . . Any recoil control mechanism must likewise close in on the force before the force starts to move things. If it fails to get on the job on time then it is not a control mechanism—it is merely some sort of stopping mechanism—much as your jaw would be if you delayed closing in on the man's fist until after he had gotten it started . . . The Watson Company has never, nor will it ever, turn out a control mechanism that fails to get on the job at the very inception of the recoil movement. That is why all Watson mechanisms DO CONTROL. To the best of our knowledge, this can be said of only one other shock absorbing mechanism which has ever been offered on the market.

JOHN WARREN WATSON COMPANY
PHILADELPHIA, PA.



PRESIDENT

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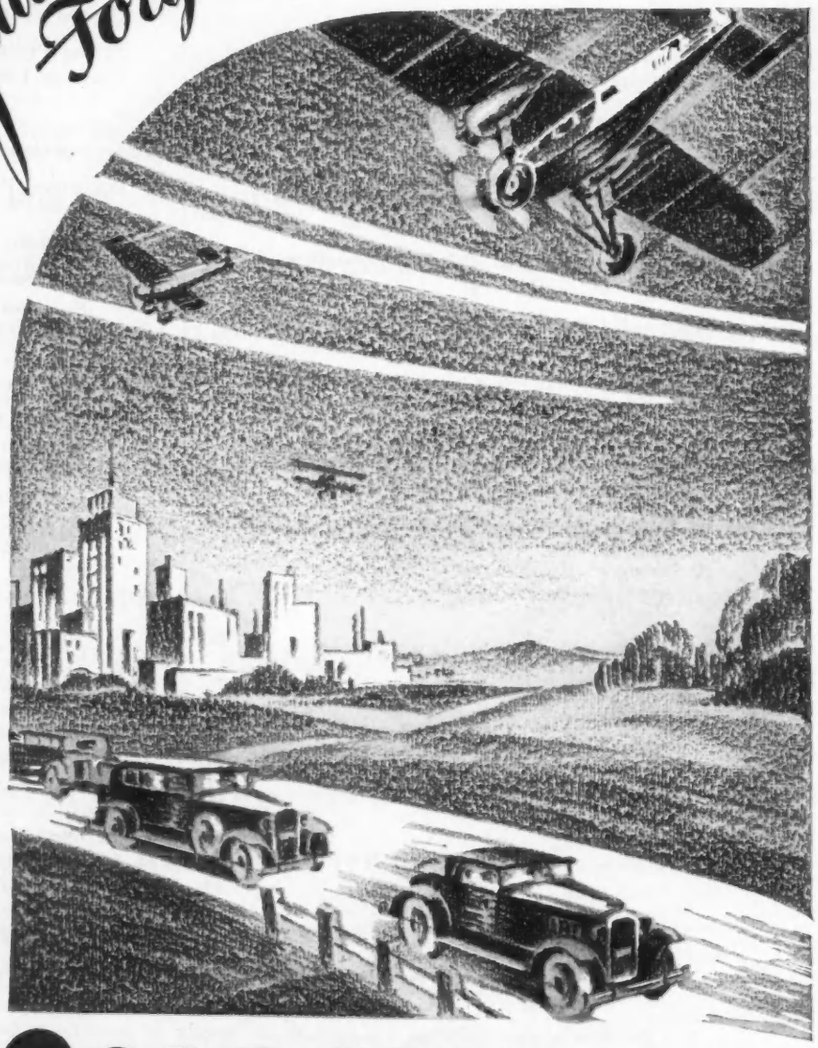
The purpose of meetings of the Society is largely to provide a forum for the presentation of straightforward and frank discussion. Discussion of this kind is encouraged. However, owing to the nature of the Society as an organization, it cannot be responsible for statements or opinions advanced in papers or in discussions at its meetings. The Constitution of the Society has long contained a provision to this effect.

ON THE AIRWAYS TO-DAY

Guaranteed Forgings

– as on the highways for the last 30 years –



WYMAN-GORDON

WORCESTER, MASS. AND HARVEY, ILL.

Spring Production Meeting Big Success

Milwaukee Section Provides Interesting Two-Day Program of Technical Papers and Visits to Local Plants

WHEN THE 1930 Production Activity Committee planned last year for a Spring Production Meeting of the Society, the Milwaukee Section promptly invited the Activity to schedule it there. As soon as the National Meetings Committee and the Council of the Society had approved the plan, the Section immediately started to arrange the program, which included three technical sessions, three plant visits, a feature gathering by the Milwaukee Section on the first evening and a Production Dinner on the second.

The meeting was a two-day affair on May 7 and 8. The morning of the first day was devoted to registration and to a visit to the A. O. Smith Corp. automatic frame-plant, which was in full operation at the time and gave the more than 50 members and guests who visited the plant an excellent opportunity to see it working all the way down the line.

Industrial Trucks and Nickel Alloys

Immediately following luncheon, the first technical session convened, at which C. B. Crockett, secretary of the Industrial Truck Association, presented a paper on Industrial Material-Handling by Power-Driven Trucks. This paper contained much valuable production economics data and furnished direct comparison between handling raw and finished materials by means of industrial trucks suited to each particular purpose and ordinary means of handling such products. The paper was accompanied by a number of stereopticon

THOSE WHO TOOK PRINCIPAL PARTS AT THE PRODUCTION DINNER

(Left to Right) J. R. Frantz, Vice-President, The LeRoi Co. and Chairman of the Milwaukee Section, Who Presided at the Dinner. H. L. Horning, President of the Waukesha Motor Co. and Past-President of the Society, Toastmaster. Dr. E. A. Ross, of the University of Wisconsin, Who Spoke on the Aspects of Economical Production as They Affect Present Conditions

pictures illustrating the adaptation of various special types of industrial trucks to different production requirements. These were followed by a motion picture showing different types of industrial trucks in actual performance.

The next paper at this session dealt with nickel alloys in automotive manufacturing and was presented by T. H. Wickenden, of the International Nickel Co. He showed how alloy steels have played a very important part in the development of all types of automotive apparatus and how the use of nickel has also facilitated machining ability in various metals and made it possible to overcome inherently undesirable qualities in metals by the judicious use of nickel as an alloying element. Mr. Wickenden also showed where advantages can be gained by alloying nickel in materials used for production equipment such as various types of tools and in die blocks and other parts entering into the construction of machine-tools. The paper was illustrated by stereopticon views showing microphotographic comparisons of the metallurgical structure of metals with and without nickel and also a variety of castings that have been appreciably improved by the use of this alloying element.

Both papers were discussed at considerable length by many of the eighty odd members and guests who attended the session. C. L. Cole, a Past-Chairman of the Milwaukee Section, was Chairman of this technical session.

During the evening the Milwaukee Section entertained about 200 guests at a Dutch buffet supper that was thoroughly appreciated. This was followed by an informal musical program in which most of those present took part.

Plant Visits Follow Papers

Following the morning and afternoon sessions on May 8, at each of which only one paper was presented, there was a successful innovation in the arrangement for a plant visit immediately following each paper at which an interesting demonstration was witnessed.

At the morning session H. E. Koch described in considerable detail an oil-vapor process for case-hardening in his paper on New Developments in Surface Hardening of Steel and Their Effect on Cost of Production. The paper was illustrated by stereopticon views and contained a number of interesting cost comparisons. The session was ably presided over by Eugene Bouton and was attended by about 75 members and their guests, who adjourned the session to witness a practical demonstration at the Hevi-Duty Electric Co. plant of deep case-hardening in the furnaces that Mr. Koch had described at the technical session.

J. B. Armitage presided as Chairman at the afternoon session, at which F. W. Curtis gave a valuable paper on Latest Developments in High-Speed Milling with Tantalum and Tungsten-Carbide Cutters. Those who attended this session, to the number of about 250, were given an excellent description of the successful development of high-speed heavy duty milling-cutters and a list of "do's" and "don'ts" for their successful design and operation. Immediately following the session about one-half of those who attended the meeting went to the Kearney & Trecker Corp. plant, where demonstrations were made of high-speed milling of various metals in commercial production. These operations were demonstrated in groups of machine-tools at each of which an amplifier was used by a representative of the corporation to describe the machining process while it was performed and the results of each compared with ordinary methods.

The Production Dinner on the evening of May 8 was presided over by J. R. Frantz, Chairman of the Milwaukee Section. Following announcement of the results of the election of new officers of the Milwaukee Section for the coming year, he introduced Past-President of the Society H. L. Horning, the toastmaster. Toastmaster Horning, after making a few of his characteristically pertinent remarks concerning the present economic situation, referred to by some as a depression, gave a brief biographical outline of the principal speaker's career and accomplishments, and introduced Dr. E. A. Ross, professor of sociology at the University of Wisconsin.

Capitalism and Labor

Dr. Ross discussed capital investment and labor in industry. He said

CHAIRMAN AND SPEAKERS AT THE SESSION SPONSORED BY THE NATIONAL SOCIETY

(Left to Right) Thomas H. Wickenden, of the International Nickel Co., Who Presented a Paper on Nickel Alloys in Automotive Manufacturing. Cyrus L. Cole, Vice-President and Engineer of Williams, Cole & Wolff, Inc., Chairman of the Session. C. B. Crockett, Secretary of the Industrial Truck Association, Who Gave a Paper on Industrial Material Handling by Power-Driven Trucks

CALENDAR

National Meetings

Summer Meeting—June 14 to 19
Greenbrier Hotel, White Sulphur Springs, W. Va.

20th National Aeronautic Meeting—Sept. 1 to 3
Hotel Statler, Cleveland
In conjunction with the National Air Races

Production Meeting—Oct. 7 and 8
Book-Cadillac Hotel, Detroit

Transportation Meeting—Nov. 10 to 12
City of Washington

June Section Meetings

Buffalo—June 6
Outing—Buffalo Launch Club, Grand Island

Canadian—June (?)
Water trip on Toronto Harbor

Metropolitan—June 6
Fort Hancock Beach Party

Oregon—June 6
Inspection of Army Planes at Pearson Field, Vancouver, Wash.

Philadelphia—June (?)
Golf Meeting

St. Louis—June 6
Inspection trip to Union Electric Light & Power Co. Dam and Artificial Lake at Bagnell, Mo.

that invested capital per worker is from 11 to 12 times what it was a century ago and predicted that in 40 years the capital invested per worker may be $10,000. The share of national product going to capitalists for the use of their money is computed to be about 35 per cent in the industrial field. When in the distant future the investment becomes $15,000 to $20,000 per worker and two-thirds to three-quarters of the total net product goes to capitalists, we shall have either capitalistic feudalism or the replacement of private capitalism by public capitalism.

The speaker inquired if it would not be intelligent to forestall such an outcome by what he called "industrial dualism." The basis of such a division between private and public capitalism is afforded by the fact that branches of industry differ greatly in their degree of capitalism, in one branch the worker cooperating with $1,000 of capital while in another he cooperates with $25,000. In the first, he said, perhaps 3 cents of the consumer's dollar goes for hire of capital; in the other, possibly 75 cents. In the latter case it may be 25 times as important to lift from the consumer the burden of capital charge as in the first case.

On this line of reasoning, Dr. Ross indicated the desirability of public construction and ownership of public services, power development and mines as well as public buildings, so that when the bonds are retired the public will be freed of the perpetual charge for use of private capital. Manufacturing, however, would constitute a field in which "private capital might disport itself indefinitely."

Material Handling by Truck

Materials handling is a by-product of low-cost mass-production methods and it is in the smooth fast movement of raw materials and semi-finished parts that the automotive industry has achieved such outstanding economies, according to C. B. Crockett. Continuing, he remarked that it has even been said that in the planning of an automotive plant the actual production operations performed are secondary in importance to the problem of how the material will flow from one operation to the next. In considering the place of electric industrial trucks in the general handling system, he made two classifications of handling problems—handling on the actual production line and handling by periodic movement of materials not always uniform nor for the same destination—before discussing the requirements of the problems and the characteristics of the different classes of equipment that may meet these requirements.

The principal handling operations in any manufacturing plant were stated by Mr. Crockett as being the movement of raw materials from a common carrier to storage or to the process, of materials from storage to the process, of materials through the process and the assembly, of finished products from storage to shipment, and of supplies, machine parts and machines to and from the point of use.

CHIEF PARTICIPANTS IN SECOND DAY'S SESSIONS, SPONSORED BY THE MILWAUKEE SECTION

(Top) Eugene Bouton, Supervisor of Time Study, J. I. Case Co., Chairman of Forenoon Session. H. E. Koch. Research Department, Hevi-Duty Electric Co., Who Told of New Developments in Surface Hardening of Steel

(Bottom) J. B. Armitage, Chief Mechanical Engineer, Kearney & Trecker Corp., Chairman of the Afternoon Session. F. W. Curtis, of the Kearney & Trecker Corp., Who Presented a Paper on High-Speed Milling with Tantalum and Tungsten-Carbide Cutters

Conveyors of all types are without doubt the most economical mechanical equipment where the continuous flow of material is sufficient to warrant a comparatively high capital investment and where the chances of a change in the operation are not likely within the period required to pay off the investment, said Mr. Crockett. If the quantities moved are smaller than that required to install conveyor equipment economically, a periodic method may be adopted for movement between operations. The essential principle of periodic movement, for which the power truck is admirably suited, is the increase of the size of the unit load moved and the elimination of individual handlings at the beginning and the end of the operation.

New methods of handling sheet steel were cited, and a typical illustration of the use of electric trucks in this service was given. Skid shipment, that is,

interplant shipment of material on skid platforms either by rail or by motor-truck, was stated to be a rapidly growing practice. Examples of such handling were given, comparisons being made between the former method and this new method. The author pointed out the many variable factors existing in any materials-handling problem and the difficulties incurred in selecting the equipment which will result in the lowest over-all cost during a period of years. A brief discussion was devoted to the proper field for all types of mechanical equipment, to indicate more clearly that in which the power truck has been most advantageously applied. Recent applications of the equipment were described and examples of costs and savings were given.

Wickenden on Nickel Alloys

Thomas H. Wickenden, of the International Nickel Co., discussed at the first technical session the uses of nickel alloys in the automotive industry. He listed eight advantages that can be secured by proper use in cast iron of nickel by itself or in combination with other alloying elements. Nearly all of these can be utilized in cylinders, cylinder-heads and manifolds of automotive engines. Effects of varying the content of silicon and nickel and of annealing were discussed. Small additions of nickel and chromium have increased the mileage between grinding valves by five to seven times, while in heavy-duty engines the hardness of valves seats thus secured has eliminated trouble from pounding in of the valves. Porosity in manifolds and cracking and growth in heavy-duty units are prevented by lowering the silicon content and adding nickel or nickel and chromium.

Excessive quantities of free carbon result in difficult machining and irregular wear, while free ferrite makes the iron soft and too easily worn when used in cylinder-blocks.

Chromium has a marked hardening effect upon iron but results in serious machining difficulty if a definite nickel content is not included. From 2½ to 3 per cent of nickel is required to neutralize the tendency of the chromium to form hard iron carbides.

For use in brake-drums of heavy-duty vehicles and passenger-cars where it is desired to save weight, high-test iron should be used, said Mr. Wickenden. This is produced from a high-steel mixture having a silicon content of 1.5 to 1.75, a nickel content of 2.0 to 2.5 and in some cases a chromium content of 0.20 to 0.30.

Mr. Wickenden also discussed the use of nickel cast-iron in dies and other heavy wearing parts, heat-treating for high hardness, and irons for use at elevated temperature.

The latter portion of the paper was devoted to nickel steels as used in steering-knuckles, gears, axle shafts and the like and also in production tools, especially forging die-blocks. The speaker dealt with their machining and heat-treating and with the heat-resisting nickel-chromium steel alloys which he said are responsible for revolutionizing automotive production, particularly through the use of various automatic furnaces.

Developments in Surface Hardening

H. E. Koch, of the research department of the Hevi-Duty Electric Co., presented developments that have

PRESCOTT C. RITCHIE

Advertising Manager of the Waukesha Motor Co. and Secretary of the Milwaukee Section

grown out of research work carried on in connection with nitriding equipment. Two reasons were said to have led to this development: First, many nitriding furnaces were found to be without work enough to keep them busy, hence economics made desirable some utilization of this idle capacity. Second, developments in nitrided products demanded an improvement in the quality and reduction in the cost of carburizing.

Similarity exists between nitriding with ammonia at from 900 to 1200 deg. fahr. and carburizing in a gaseous atmosphere at temperatures between 1650 and 1750 deg. fahr. Carburizing of this sort dates back to the middle of the 19th century, but recent activity in this line has created the impression that it is something new; in fact, the acceptance of the process on a broad scale is relatively new.

Early applications of the gaseous carburizing art had as their object the production of a sort of steel from wrought iron, and many designs and processes were proposed for producing armor-plate. The electrically heated gas carburizer is a comparatively recent development which gives accuracy and ease of temperature control. The vertical carburizer, moreover, adds forcible circulation of the carburizing gas, which gives unusual results.

The vertical furnace contains a closed retort inside of which is a work-holding basket, a centrifugal fan having central suction and lateral discharge. The cycle of operations includes loading the basket, bringing the charge up to carburizing temperature, introducing the carburizing gas and holding the heat for the required time, holding the heat further without gas flow, and removing the retort or the basket only for quenching or otherwise cooling the work. Similarity between this process and that of nitriding is apparent.

City gas available in many sections, particularly if it is natural gas, is a good carburizing medium. However, each locality presents its own peculiar problems. The only limitation ordinarily imposed upon the supplier of the gas refers to its heat content; the chemical constituents may vary enough to disturb the carburizing operation. For this reason a blended chemical mixture has been developed which will vaporize to produce the same results wherever the furnaces are used. This is available if local gas will not produce satisfactory results.

Carburized sections now are controlled by specifications covering the structure itself as well as the depth of case. Limits are placed on the hypereutectoid, the eutectoid and the hypoeutectoid or graduation zone. The gas carburizing process has the capacity to control the case structures to meet such rigid specifications.

Carburizing time required in this process was said by Mr. Koch to be remarkable. Penetration takes place in normal S.A.E. 1020 steel at the rate of 0.012 to 0.015 in. per hr. when the charge is at 1700 deg. fahr., and at a somewhat faster rate in pearlitic manganese steels designed especially for carburization. An example shown, which was produced in 10 hr. at heat, has a case depth of approximately 5/32 in.

Mr. Koch concluded with tabulated comparative data on fluid carburizing and box carburizing.

New High Speed Milling

Tungsten carbide has unquestionably revolutionized manufacturing methods during the last three years, Mr. Curtis said, and its value cannot be questioned. Every new product has its limitations as well as its possibilities, and lack of early knowledge of the limitations of this material caused enough failures to cast doubt upon its possibilities. Most of these failures, Mr. Curtis said, have been due to one or more of the following causes: a poorly designed tool, either too weak or of incorrect shape;

lack of support for the tool; application in an unsuitable machine-tool, either badly worn or too small; poor fixtures, in which the work is inadequately clamped; and carelessness, as a result of insufficient application of knowledge.

Milling is an outstanding service for tungsten carbide, but applications in this field have not kept abreast of those in other operations. As the work to be done by the cutter is divided among several teeth, the cutter can remove a large quantity of metal without overtaxing the individual teeth.

Inserted-blade cutters of various types can be designed without much difficulty to secure the full benefit of the hard material. They are solid and rigid in construction and have been highly successful. Solid-type cutters, particularly small plain and side-milling cutters, have also been used with good success, but their application is somewhat limited. When a number of inserts are brazed solidly into a steel body, the replacement of a damaged insert is likely to necessitate the complete rebuilding of the cutter, because the brazing heat is liable to loosen other tips. An alternate construction is to make small carbide-tipped blades which are pressed and tack-welded into slots in the body of the cutter before the tips are finish-ground. In some cases it is possible to remove and replace such blades with little difficulty.

Strength and Rigidity Imperative

Three outstanding requirements for tungsten milling-cutters are ample strength and rigidity, adequate support of the blades or inserts directly back of their cutting edges and positive locking of the blades.

Development in milling-machines has been so rapid, according to Mr. Curtis, that few of the older machines are likely to be suitable for use with tungsten-carbide tools. When a machine shows a tendency to develop chatter, its use with this tool material must be abandoned immediately if the chatter can be stopped.

Savings are possible in the amount of finish provided on castings, because the tools are indifferent to scale. Reducing the depth of cut makes fast milling possible, but reasonable uniformity in the castings must be maintained to prevent depth that is excessive for the rapid feed. New fixtures may be required, either to provide sufficient rigidity or to make the loading time proportional to the cutting time.

Difficulty has been found in cutting steel with tungsten carbide because the affinity between the two metals causes them to adhere. Mr. Curtis said that this difficulty does not exist with tools made from tantalum carbide, which has many of the properties of tungsten carbide and is being used successfully on steel.

A New High for the Year

Summer Meeting Stock Advances in Value and Promises Substantial Dividends to Investors

THE RARE, not to say unprecedented, combination of an investment of absolute safety with a dividend at an unbelievably high rate is offered by the Society's Summer Meeting, which will convene at White Sulphur Springs, W. Va., on Sunday, June 14, and continue until Friday, June 19.

The capital to be invested consists of one week of an engineer's time and an outlay of money sufficient to cover his expenses, and the results will more than justify the combined expenditure of time and money. Profits on the investment will begin to accrue immediately, through attendance at technical sessions and participation in the discussion of the papers presented and through informal post-session conferences, on problems of common interest, with other engineers spending the week of June 14 to 19 at White Sulphur. After returning from the Summer Meeting, each engineer who took part in the activities will continue indefinitely to derive profits from the investment, both for himself individually and for his company, by putting into his work the enthusiasm derived from attendance at the sessions and by employing ideas that he obtained directly from technical data presented in papers and discussion or that he gained indirectly through stimulating contacts and associations.

Attractive Technical Program

The six-day program comprises a standards session and 12 technical sessions at which 26 papers are scheduled for presentation. Many of the papers will be available in advance, in mimeographed or printed form, and copies when available will be sent upon request.

Chairman Norman G. Shidle, on behalf of the National Meetings Committee, announces that each session will start promptly at the time specified in the program and that each paper will have a definite time limit which shall not be exceeded. Strict adherence to a predetermined schedule will, it is believed, allow more time for discussion than would be possible in the case of sessions less carefully organized.

An idea of the value of the meeting, quantitatively speaking, can be derived from a perusal of the program on p. 613. Its qualitative worth can be partly realized by a study of the abstracts of papers on p. 612. But a true comprehension of the profit to be derived from the meeting can be obtained only by actual attendance and participation, by hearing the papers when presented, listening to discussion and taking part in it, later joining in the informal session-after-the-session and associating informally with other engineers of equal keenness and similar interests.

Recreational facilities will include golf, tennis, archery and swimming, with bridge specially arranged for the ladies who come to the Summer Meeting. A semi-humorous water carnival on Monday evening (be sure to bring your bathing suit), a field day on Wednesday afternoon that will exercise all the laughter muscles, dancing each evening and a grand ball on Thursday evening will be enjoyable features of the week.

The *Daily SAE*, without which the breakfast table at Summer Meetings would be incomplete, will be published this year through the courtesy of the Edward G. Budd Mfg. Co., of Philadelphia.

How to Get There

Special trains to White Sulphur Springs will be run on June 13 from New York City, West Philadelphia, Baltimore, Washington, Detroit, Cleveland and Toledo, and special trains for the return trip will leave White Sulphur on June 19. Railroad schedules for these trains were included with the Meetings Bulletin mailed to all members on May 15, together with directions regarding the fare-and-a-half railroad ticket and the making of Pullman reservations.

Automobile routes to White Sulphur Springs from New York City, Pittsburgh, Cleveland, Detroit and Indianapolis have been furnished the Society by the American Automobile Association, and these routes were printed in the Bulletin just mentioned. Members are advised to consult their local automobile club for maps and for last-minute road data.

Airport facilities at White Sulphur Springs are reported to be excellent. If members will write or wire S. A. E. Headquarters, 29 West Thirty-ninth Street, New York City, complete details regarding the Greenbrier Airport will be promptly furnished.

Do It Now!

An application blank for hotel reservations also accompanied the Meetings Bulletin on May 15, and the number of applications received points to a splendid attendance. Members who have not yet made application but desire to do so are urged to send in their applications without delay.

What the Papers Tell

Rating the Motor-Truck.—"Truck ratings are so misleading that many large operators disregard the manufacturer's ratings." A discussion of factors involved in truck ratings, with simple basic formulas suggested for determining capacities.

A Suggested Basis for Rating the Ability of Motor-Trucks.—A brief discussion of truck development, with an itemized treatment of the factors involved in rating. These factors combined in a rating formula, with tables for its application. A basis for applying the formula in comparing various trucks.

Carbureter Design for the Fuel-Research Detonation Engine.—Specific design and performance figures on a special carbureter that provides essentially constant mixture ratio for different throttle positions. This carbureter has been developed for use with the fuel-research engine that is being applied to the detonation studies of the Co-operative Fuel-Research Committee.

The Interpolation Method in Detonation Testing.—A discussion of the permissible interpolation interval for detonation testing as affected by octane number, engine and adjustment of the bouncing-pin system.

Further Developments in Determining Gum in Gasoline.—Forecasting the gum-forming possibilities of given fuels for use in internal-combustion engines.

Fuel-Line Temperatures in 1931 Motor-Cars.—Pointing out the relationship between car design and layout features as they influence vapor lock. A diagnosis of existing conditions in current production cars. An opportunity for automobile and fuel engineers to further the solution of a vital problem.

Utilization of Motorcoaches.—With millions invested in motorcoaches, the electric-railway industry has ideas regarding features to simplify production and improve operation. A presentation of these requirements, a study of localized conditions and a statement of results of research by manufacturer and carrier.

Automotive Diesel Fuels.—A brief history of Diesel-engine fuel oil and its manufacture and data on the control of combustion in high-speed Diesel engines and on the physical and chemical characteristics of several Diesel-engine fuel oils, together with test results obtained from various engines.

The Tear-Drop Car.—"If we started out today to design a fast automobile and were not handicapped by precedent and fashion, said automobile would not look, or act, or be mechanically arranged like present automobiles. * * * Although in the beginning there was reason and justification for the development of a slow-moving automobile, in appearance and arrangement along the lines of the horse-drawn runabout and milk wagon, there is today public requirement of such speed, economy and comfort in automobile transport as to demand engineering, new and strictly up to date." Layouts, illustrations and actual test results on full streamlined cars.

Practical Experience with Devices for Damping Torsional Vibrations.—A discussion and analysis of the various devices now in use for damping torsional vibration in crankshafts of Diesel engines.

Comfort and Interior Appointments.—"You cannot cut a piece off the passenger to fit the body, for the passenger wishes to take all of his anatomy into the vehicle with him. * * * It is practically impossible to build a comfortable cushion to fit over a small size dishpan projecting 2 or 3 in. up into the bottom of the rear cushion." Note: It is *practically impossible* for this to be other than a refreshing exposition of how to build passenger-car bodies to carry passengers, not freight.

What the Body Designer Wants in a Chassis.—Frame rigidity and dimension requirements, body-weight-reduction possibilities with properly designed frames, suitable anchorage provisions between body and frame, coordination of design and construction phases. A pointed consideration of body-chassis problems involved in the appearance and life of the car; an opportunity for all sides of a many-sided subject to be presented.

Driving High-Speed Cars.—Believing that very few car owners know how to handle a car going above 60 m.p.h. in cases of emergency, the author of this paper will analyze specific predicaments and their solution in terms of driver, vehicle and builder responsibility.

The Field for Synthetic Lubricating Oils.—A comprehensive exposition of physical properties and interesting uses of a new series of *synthetic* oils with smaller temperature-viscosity coefficients than are otherwise available, freedom from cold test or plastic characteristics, and other remarkable qualities. Performance data and possibilities of these new products applied to engines, transmissions, steering mechanisms, shock-absorbers and other automotive mechanisms.

The Case for Rear Engine-Mounting.—With the engine mounted at the rear of the chassis, come greater passenger space and comfort; less noise, heat and odor; improved streamline form; more compact and better-balanced engines; concentration of power and transmission parts where they are accessible and easily lubricated from one source; decrease in body and vehicle weight; better riding-qualities and visibility; elimination of exterior parts and accessory mountings. A thorough discussion of body and chassis problems, with illustrations of layouts already developed and proposed.

Flying with the Navy.—A résumé of naval aviation describing the operations of the Navy Air Service at sea, accompanied by motion pictures illustrating many of the recent maneuvers held in the Pacific Ocean off Panama. The relation of aircraft to successful naval operations, and the position of the United States with regard to other countries in the matter of naval aircraft equipment.

Air-Cooled Cylinder-Head Design.—A review of recent developments in air-cooling for reduced temperatures at increased outputs, suggesting lines for further investigation of air-flow behavior over finned bodies simulating cylinder-heads.

Recent Valve Developments.—Latest developments in valves, especially those used in aircraft engines. Information on processes, seat and guide temperatures, lubrication, corrosion and materials. An answer to the demands for higher power in present engines.

The Tire Factor in Automobile Riding-Quality.—Properties affecting the riding-qualities of tires; interrelation of major characteristics of various elements of the elastic suspension systems; typical instruments and measurements. A new method of accurately measuring traction between tire and road under actual service conditions will be described.

Road Tests with the New Wabblemeter.—Initiation of a program to coordinate the fatigue results as shown by the wabblemeter with a limited measurement of the behavior of the vehicle on the road.

Some Observations on Riding-Qualities.—Observations on drivers of many cars during Indianapolis Speedway runs. Evaluation of fore and aft accelerations in modern automobiles. Observations on the effects of vertical vibrations of stated amplitudes and frequencies on men and women of various ages and weights.

Instrumentation as a Means for Coordinating Chassis and Body Design.—"Squeaks, rattles, broken body-brackets and corner posts are the fault of the frame designer." "The h . . . you say! If the body engineer would put some stiffness into his body, *where it belongs*, all body and chassis trouble would be

Summer Meeting Technical Program

White Sulphur Springs, W. Va. — June 14 to 19

Sunday, June 14

8:30 P.M.—Motor-Trucks and Motorcoaches
H. W. Alden, *Chairman*

Rating the Motor-Truck
M. L. Pulcher, Federal Motor Truck Co.

A Suggested Basis for Rating Truck Ability
L. R. Buckendale, Timken-Detroit Axle Co.

Monday, June 15

10:00 A.M.—Diesel Engines
W. F. Joachim, *Chairman*

Automotive Diesel Fuels
W. H. Butler, Standard Oil Co. of New Jersey.

Devices for Damping Torsional Vibrations
Erich Sandner, Consulting Engineer, Dortmund, Germany, and J. B. Frauenfelder, Consulting Engineer, Philadelphia.

10:00 A.M.—Transportation
F. K. Glynn, *Chairman*

Utilization of Motorcoaches
D. A. Smith, Department of Street Railways, Detroit (Through cooperation of American Electric Railway Association).

Utilization of Motor Trucks
A. H. Gossard, Middle West Utilities Co. (Through cooperation of National Electric Light Association).

8:30 P.M.—Fuels
A. L. Beall, *Chairman*

Carbureter Design for the Fuel-Research Detonation Engine
C. S. Kegerreis, Consulting Engineer, Toledo.

The Interpolation Method in Detonation Testing
D. B. Brooks, Bureau of Standards.

Developments in Determining Gum in Gasoline
O. C. Bridgeman and E. W. Aldrich, Bureau of Standards.

Fuel-Line Temperatures in 1931 Motor-Cars
O. C. Bridgeman and H. S. White, Bureau of Standards.

Tuesday, June 16

10:00 A.M.—Passenger-Car Bodies
L. C. Hill, *Chairman*

Comfort and Interior Appointments
H. A. Brunn, Brunn & Co., Inc.

What the Body Engineer Wants in a Chassis
R. F. Anderson, Murray Corp. of America.

8:30 P.M.—Passenger-Cars
W. C. Keys, *Chairman*

Driving High-Speed Cars
J. E. Hale, Firestone Tire & Rubber Co.

The Tear-Drop Car
W. T. Fishleigh, Consulting Engineer, Detroit.

Wednesday, June 17

10:00 A.M.—Future Developments
G. L. McCain, *Chairman*

The Field for Synthetic Lubricating Oils
F. W. Sullivan, Jr., V. Voorhees, P. T. Oak, D. P. Barnard, Standard Oil Co. (Indiana).

The Case for Rear Engine-Mounting
Herbert Chase, Consulting Engineer, New York City.

10:00 A.M.—Standards
Arthur Boor, *Chairman*

Reports of the various Divisions will be presented and acted upon.

8:30 P.M.—Semi-Annual Business Meeting
President Vincent Bendix in the Chair.

8:30 P.M.—Aircraft
Dr. G. W. Lewis, *Chairman*

Flying with the Navy
Hon. D. S. Ingalls, Assistant Secretary of the Navy for Aeronautics.

Thursday, June 18

10:00 A.M.—Aircraft Engines
Arthur Nutt, *Chairman*

Air-Cooled Cylinder-Head Design
Roland Chilton, Wright Aeronautical Corp.

Recent Valve Developments
A. T. Colwell, Thompson Products, Inc.

10:00 A.M.—Chassis
E. S. Marks, *Chairman*

The Tire Factor in Automobile Riding-Quality
R. W. Brown, Firestone Tire & Rubber Co.

Road Tests with the New Wabblemeter
Dr. F. A. Moss, George Washington University.

Some Observations on Riding-Qualities
Dr. Ammon Swope and Prof. H. M. Jacklin, Purdue University.

Instrumentation as a Means for Coordinating Chassis and Body Design
A. F. Denham, *Automotive Industries*

8:30 P.M.—General Production Session
E. K. Wennerlund, *Chairman*

Cost to Industry of Labor Turnover
H. L. Horning, Waukesha Motor Co.

Friday, June 19

10:00 A.M.—Engines
G. C. Brown, *Chairman*

Reducing Horsepower and Noise of Automotive Cooling-Fans
A. D. Gardner, Automotive Fan & Bearing Co.

Oil Consumption as Affected by Engine Characteristics
H. C. Mougey, General Motors Corp.

Low-Temperature-Starting Development of Automobile Engines
P. J. Kent, Chrysler Corp.

gone." A clear-cut statement of body-chassis problems, with a description of instruments and methods that are helping to answer them in numerous plants. If your fenders wabble, don't miss this one.

Cost to Industry of Labor Turnover.—An industrial leader bases his address on the theme that the indirect and intangible results of labor turnover are more important than the measurable costs, and that stability of industry and steady employment are the problems facing industry of the future.

Oil Consumption as Affected by Engine Characteristics.—Winter starting and winter lubrication require light oils, but light oils "go through" too fast. Practical suggestions for overcoming present difficulties.

Low-Temperature-Starting Development of Automobile Engines.—New cold-room data and full information regarding cold-starting requirements, including means for cranking fast enough and long enough; positive fuel supply to the carbureter; mixing and delivering of fuel and air in proper proportions for firing; igniting the mixture; helping large-displacement engines to carry the friction load until the engine is freed up enough to carry it. This work is based upon the belief that satisfactory cold-starting should be accomplished without the exercise of skill or special knowledge on the part of the operator.

Reducing Horsepower and Noise of Automotive Cooling-Fans.—New data on performance characteristics of cooling fans with particular reference to power requirements, output, efficiency, size, and number and spacing of blades. Recent developments in the reduction of actual and apparent fan noise.

Ordnance Committee Meets

Society's Advisory Group Considers Designs of Ordnance Department for Mechanized Force

LIEUT.-COL. A. F. MASURY, Chairman of the S.A.E. Ordnance Advisory Committee, was able to announce practically complete attendance of his Committee, which reported for action on April 27 at Fort Eustis, Va., headquarteers of the Ordnance Department's Mechanized Force. On the following day the Committee reconvened in the city of Washington and reviewed various designs that were submitted by Col. C. M. Wesson, Chief of Technical Staff, for comments and advice.

LIEUT.-COL. A. F. MASURY

At Fort Eustis, Col. Daniel Van Voorhis, in command, staged a very well organized inspection and demonstration of tanks, armored cars, trucks and special equipment, including the recently developed Christie tank. Neighboring points of historical interest were seen by Committee members during their short stay in Virginia.

At Washington, Colonel Wesson called for a detailed consideration of the suitability of the designs of the Ordnance Department vehicles of the Mechanized Force, including the Christie tank and several other armored vehicles of various types.

A special luncheon, tendered by the Washington Post of the Army Ordnance Association, was held at the Army and Navy Country Club, where the guests enjoyed remarks by Lieut.-Col. C. G. Mettler, President of the Post, and Representative John Q. Tilson.

The Ordnance Advisory Committee and guests were entertained at a dinner given by the Army Ordnance Association, at which addresses were made by Major-Gen. Samuel Hof, Chief of Ordnance, and Major-Gen. G. V. H. Moseley, Deputy Chief of Staff.

Society members who attended the various events included, in addition to Ordnance Department representatives, Lieut.-Col. A. F. Masury, Col. H. W. Alden, Col. William G. Wall, Major A. W. Herrington, P. E. Holt, Col. G. A. Green, F. C. Hecox, J. F. Winchester, A. J. Scaife, H. T. McDonald, Col. Paul Weeks and John A. C. Warner.

Papers That Click

A NUMBER of comments recently heard indicate the high quality of papers that are being presented at meetings of our Society. In the case of National meetings, these papers are acquired through the good offices of members of our various Activity Committees.

To cite the Summer Meeting as an example of the process of formulating a meeting that abounds in papers that are worth while, it is interesting to note the various steps that are bound to lead to a successful conclusion. First, the National Meetings Committee receives from each Activity a request for a given number of sessions at the Summer Meeting. The National Meetings Committee assigns the sessions, and each Activity, through its Meetings Committee, decides, on a basis of many recommendations, as to the material that is most worthy of discussion at the time and the speakers who are best prepared to present the papers. The required number of papers are then secured and the technical part of the program is complete.

It is readily seen that this process assures presentation of papers that are of real interest to those who are active in the various fields, and the speakers so chosen are outstanding in their particular lines of activity.

"For years we have been copying so faithfully that there has been nothing to argue about," quoth a speaker at a Section meeting. Members of the audience immediately started to *argue*—about thermostatic carbureter control; heating, cooling and ventilating; methods for keeping frost and ice from the windshield; independently sprung wheels; better brakes; automatic transmissions; stiffer bodies and frames; solid-injection engines; rear-mounted engines; two-cycle engines; superchargers; raindrop bodies. The party was rudely broken up by a member who remarked, "Some day, somebody's going to stop arguing and come out with a few of these ideas."

"Talking" brakes were developed and widely adopted long before the advent of talking pictures. We hear that the latter have come to stay; we hope that the former may go to stay. A speaker at one of our Section meetings informs us that chattering brakes are now understood and he infers that never again need there be noise from this source. This should be good news to some of us.

Met. Section Inspects Motor Ships

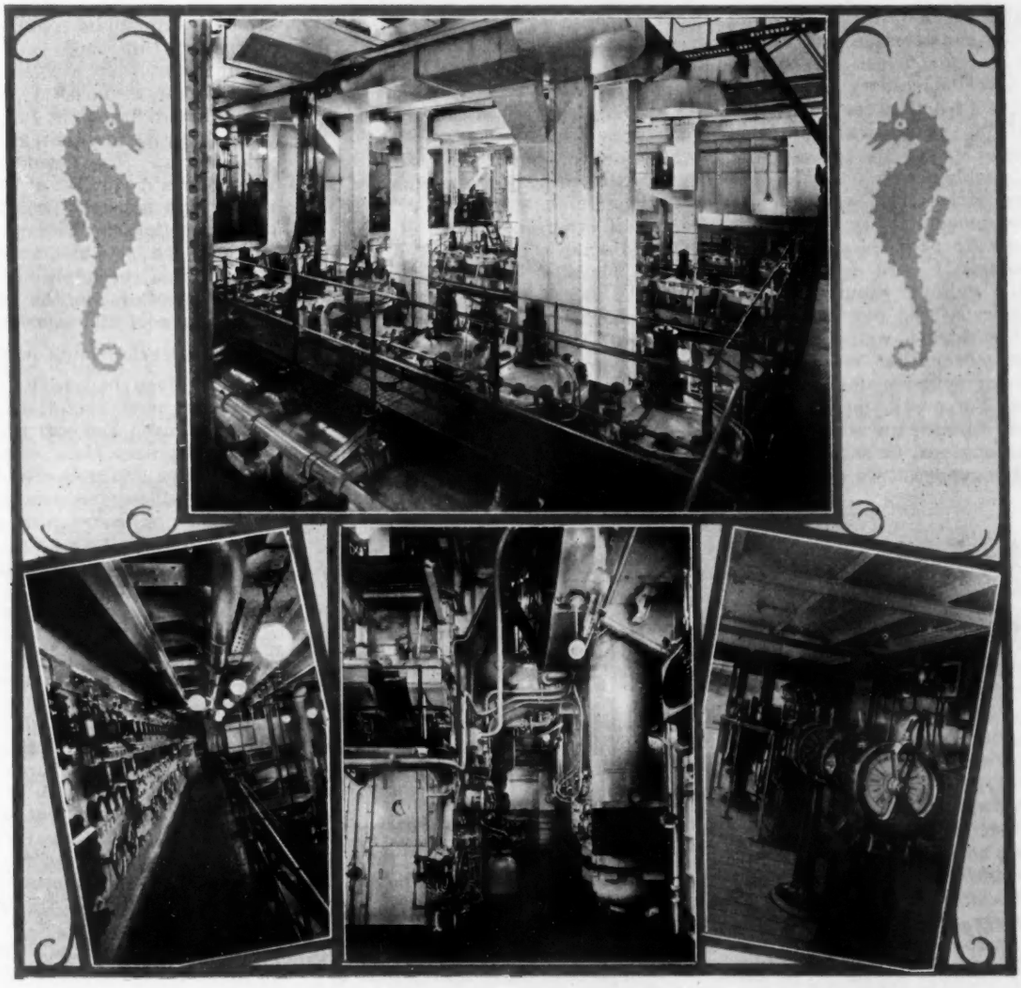
Visits Diesel-Engined Lafayette and Paris and Holds Dinner-Session on the Former

INSPECTION of the first French transatlantic motor liner, the Diesel-powered Lafayette and also the motorship Paris, by 250 Metropolitan Section members and guests was combined with a dinner and meeting on board the Lafayette on May 20. A paper on modern Diesel engine developments was presented by F. Van Rossen Hoogendyk, president of the marine engineering firm of that name. A Diesel-engined truck, furnished by the United American Bosch Corp., and a Diesel-engined bus, supplied by the New Jersey Public Service Corp., were displayed at the pier.

The Lafayette's four main driving units present a most unusual application of two-stroke double-acting Diesel machinery. Built for the Compagnie Generale Transatlantique by the Societe des Chantiers et Ateliers de St. Nazaire-Penhoët, she was put in commission only last spring. Her over-all length is 600 ft., molded breadth 77 ft. 6 in., mean draft, loaded, 30 ft. 6 in., gross tonnage about 25,000 tons. Her accommodations are for 563 cabin, 442 tourist and 72 third-class passengers and 472 officers and crew, or a total on board of 1549.

Her propelling machinery is a quadruple-screw direct-drive M.A.N. installation of the double-acting two-stroke type. Each six-cylinder engine of 23⅝ in. bore by 35½-in. stroke develops its maximum power of 4500 b.hp. at 150 r.p.m. The total maximum power of the Lafayette gives her a top speed of 18.5 knots. Two of the main engines were built under license at the Penhoët works in France, the other two at the Augsburg works of the M.A.N. under the Dawes Plan. Cylinder jackets and covers are salt-water cooled; the pistons have fresh-water cooling.

Three scavenging air turbo-blowers, each driven by a 425-kw. electric motor,



SCENES IN THE ENGINE ROOM OF THE S.S. LAFAYETTE

deliver 1200 cu. m. of air per min. to the main engines. Two blowers furnish sufficient scavenging air for all main engines under normal conditions.

There are three auxiliary Diesel generating sets of 1050 hp. each and two of 750 hp. Three of these four-stroke trunk-piston airless-injection M.A.N. engines were built by the Societe Generale de Construction Mecaniques at its Courneuve plant and two at Augsburg.

Diesel-Engine Applications

Mr. Hoogendyk, whose talk followed the dinner on board after the inspection, at one time studied under Prof. M. Schroeter, assistant to Rudolph Diesel throughout his early experimental work.

The speaker reviewed the trend of modern Diesel construction and its application in various fields. He pointed out that Diesel machinery means increased radius of action for naval vessels as well as economical operation for commercial craft. He showed why two-stroke double-acting engines and supercharged airless fuel-injection are logical developments. The advantage of the two-stroke over the four-stroke type lies mainly in the fact that it allows smaller cylinder diameters. The larger cylinders of the four-stroke engines call for thicker walls, in which heat stresses occur that may become troublesome for cylinder sizes over 400 hp. The need for a still larger output per cylinder forced the building of double-acting engines, he said. According to Mr. Hoogendyk, "we may safely say that air injection will disappear entirely. Its disadvantages are higher first cost as well as upkeep, additional over-all length and weight, the presence of high-pressure air-lines and many others."

Fuel-injection methods used by various manufacturers were explained in some detail, together with the application of these various methods to truck and bus engines. Mr. Hoogendyk said in part:

The hundreds of Diesel trucks and buses which now have been in use for several years conclusively indicate that one of the largest applications of the high-speed Diesel engine will be in the automotive field, including mobile industrial equipment, such as tractors, excavators, draglines, road rollers, mobile compressor and generating plants, farm equipment, pumping sets, oil-well drilling and so forth.

Aside from its economy, its greatest advantage in this field lies in the Diesel engine's superiority over the gasoline engine in sustained power output, especially at lower speeds.

The speaker concluded with a reference to the aircraft Diesel engines produced by Junkers, Packard, Mercedes-Benz and others.

To close the season, the Metropolitan Section plans a Beach Party at Fort Hancock, Sandy Hook, N. J., on Saturday afternoon, June 6, by invitation of Col. J. C. Johnson. Members are specially urged by Colonel Johnson to bring wives, children and guests. The party will include a boat ride to Sandy Hook, swimming, fishing, games, a shore dinner and return to New York City by special train.

Aviation and Spark-Plugs

Rickenbacker Urges Participation in Schneider Races —Rohde and Paulson Discuss Plugs

SPEEDS of 400 m.p.h. in this year's Schneider Cup races and 500 m.p.h. within the next two or three years were predicted by Edward V. Rickenbacker in his address to the Washington Section on April 28. The United States, he seemed to feel, is out of the races until more public and official interest can be aroused.

Approximately 75 persons attended the dinner at the Washington Hotel. William P. MacCracken, Jr., Chairman Elect, acted as toastmaster and introduced Otto C. Rohde, chief engineer of the A. C. Spark Plug Co., and George M. Paulson, chief engineer of the B. G. Corp., both of whom delivered papers on spark-plug developments. After opening the meeting, Clarence Bruce, Chairman of the Section, turned the meeting over to the Chairman Elect.

Among those present were Dr. H. C. Dickinson and Dr. H. K. Cummings, of the Bureau of Standards; Captains S. R. Henry, F. R. and L. F. Williams, and D. G. McGregor, all from the Tractor Section of Fort Meade, and John A. C. Warner, General Manager of the Society.

Aviation Improvements Foreseen

Mr. Rickenbacker asserted that but for air-mail contracts we should not have much aviation in this Country, which owes to the air mail a large part of its aeronautic progress. An air-mail subsidy of $600,000,000 could work vast changes in our flying equipment and general aeronautic development. A cruising speed of 200 m.p.h. is essential and will be developed in the near future. The continent will be crossed in 15 hr. in regular service. Commercial flying needs improvements in many directions.

Although the Department of Commerce has done much to make flying safe, continued the speaker, many more meteorological stations are needed and all of them must have radio communication with all terminals from which planes are leaving.

Larger and Better Engines Needed

Mr. Rickenbacker said that larger and cheaper engines are necessary. He predicted that engines of 24, 36 or even 48 cylinders may be developed, that engines probably will be enclosed in the wings or in the central portion of the airplane, and the propellers will be driven by shafts. Better contour-altimeters, to indicate height above ground, and a wider use of automatic pilots are needed. Radio beacons will be more widely used. Superchargers probably will be further developed, and later two-cycle and Diesel engines.

As the Indianapolis race track has been the proving ground for nearly all of our automobile improvements, the Schneider Cup races are the proving ground for fast airplanes needed in time of war, declared Mr. Rickenbacker. The United States is far behind some of the European countries in speed developments. The development of racing planes requires a great deal of money and research, and no individual or corporation can be expected to carry on the work. As the whole public will benefit from the knowledge gained and improvements made, the public's money should support our entry into the races.

Recent Developments in Spark-Plugs

Spark-plugs had to be developed to meet the new conditions as engines were improved and superchargers were introduced, said Mr. Rohde in his address. Hot plugs were developed in which the electrodes attain higher temperatures and do not foul readily. Cold plugs have electrodes that stay cooler than those of the usual plug and do not preignite the mixture under heavy engine-loads. A customary practice is to use a hot plug in a cold engine and a cold plug in a hot engine.

As most European engines use an 18-mm. plug, this metric size has been adopted by many engine builders in this Country. Some builders have asked for a 12-mm. size and some experimenting has been done with it but the results have not been entirely satisfactory. The ⅞-in. size is still widely used. From the viewpoint of the manufacturer and distributor, keeping the number of sizes to the minimum is highly desirable.

Recent work in the laboratory has developed three types that have been found to meet most of the needs of conventional engines, continued Mr. Rohde. A projecting core gives a plug that can be used over a wide range. Hot plugs have a greater area of the porcelain exposed to the burning gases in the engine. Cold plugs extend the shoulder of the porcelain down nearer to the electrode, thus reducing the area exposed to the hot gases.

Mica plugs have been more generally used in the large aircraft engines since the World War, said Mr. Paulson in his

address. The dielectric strength of mica is very high, and very little thickness is required to give the necessary insulation if the mica is not injured in assembly.

The resistance of a plug to fouling depends upon the length of the flash-over portion of the mica exposed to the cylinder gases and on the temperature at which that portion is maintained. The greater the length is, the greater is the resistance to fouling; however, if such plugs are used in the wrong types of engine they may cause pre-ignition under heavy loads.

Spark gaps on aviation engines are usually set at 0.012 to 0.015 in. and not allowed to burn to greater than 0.025 in.

The use of radio created a new problem for spark-plug manufacturers. A good radio-shielded plug should give protection from rain and oil and from machine-gun and exhaust-gas fouling on the outside of the plug.

Student Activity Fostered by Detroit Section

A DEFINITE step toward making the student activity a permanent responsibility of the Detroit Section has been taken by making Alex Taub a Vice-Chairman of the Section in charge of Student Activity and directing him to maintain and further the student cause, Phil Kent, Chairman of the Section, told the students and juniors assembled at the meeting held on April 28 in the General Motors Research Building.

Mr. Taub, in taking over the meeting, told the students of the necessity for alert minds in listening, since important suggestions are often simply stated and may otherwise escape attention.

O. E. Hunt then enlarged upon the necessity of the studious attitude of mind in business. He emphasized the necessity of team work by describing the cooperative mental processes necessary for the designing of a car and left no doubt that a successful product would never be a one-man responsibility. This is the fundamental difference, he said, between the student problem and the business problem, the former being that of an individual, the latter that of a group.

Robert N. Janeway, in a talk on Mathematics as an Engineering Tool, directed his efforts at demolishing the bugaboos of higher mathematics, using many humorous analogies to illustrate his point. He warned against the practice of using mathematics as an end rather than a means to an end. He reduced calculus to the simple fundamentals of algebra, explaining the significance of the mysterious signs of calculus in the hope that engineers would not speedily turn the pages when the calculus signs appear. He pointed out that only a few fundamental equations that will cover every phase of an engineer's requirement need to be borne in mind.

D. B. Webster, experimental engineer of the Chevrolet Motor Co., gave a talk and demonstration on Laboratory Equipment and Its Uses. Included in the demonstrations were motion pictures of various pieces of equipment in operation, including portable equipment such as the stroboscope, vibroscope and telechrome counter. He described the means used for measuring flame progress in combustion-chambers and showed how photographs are taken through a quartz window. Several slides of the resulting photographs were most interesting, as they seemed to confirm recent writings on where detonation takes place.

A stroboscope or "flicker light" that was shown consists essentially of a high-resistance vacuum-tube having a small content of neon gas, so that a heavy flash of current will produce momentarily a large volume of light. A condenser charged at a potential of about 1000 volts furnishes the current at the required high rate. This current passes through the tube only when the normally high resistance of the tube is broken down by a high-voltage impulse from the secondary winding of an industion coil, the primary current through which is interrupted by a circuit-breaker operating at a controllable frequency. The resulting high-voltage impulse of itself produces a flash in the tube, which has not enough volume to be useful, because of the low amperage. The condenser that furnishes the larger volume of current is recharged between flashes by a combination of transformer and rectifier tube.

Stop-watches are little used in the General Motors laboratory. A synchronous electric motor geared to a counter takes its place for most types of test. Such a device is especially adaptable for automatic operation, as by a float-actuated switch. The time lag in starting is said to be more than neutralized by the overrun in stopping, but this has been corrected by an adjustable friction brake so that the average error is reduced to 0.0006 min. Time is measured in minutes rather than in seconds in this laboratory.

In closing the meeting Mr. Taub told the students that a new branch of student activity is being inaugurated to include the answering of questions appertaining to automotive engineering and stated that the Governing Committee of the Section will establish a Board of Strategy for answering questions about papers and talks by direct mail and in the *Supercharger*.

Season Closed Brilliantly

Autogiro, Airships and High-Compression Problems the Subjects in Baltimore

A PROGRAM overflowing with interest was unfolded to an audience of 191 members and guests of the Baltimore Section on May 15, which brought to an auspicious close the meeting activities of the season. The splendid support of the members and the untiring effort of its officers throughout the year toward making the Section a success culminated at this meeting.

Chairman George O. Pooley introduced the new Chairman-Elect, A. Bruce Boehm, who presided and immediately proved himself a genial and able toastmaster. Other officers who will serve through the 1931-1932 season are: George Hull, Vice-Chairman; Lawrence F. Magness, Treasurer; and Espy W. H. Williams, Secretary.

Mr. Boehm announced his first appointment of committee men, that of Norton L. Dods, Past Vice-Chairman, as publicity director for the Section.

Those who attended the meetings of the season are indebted for the great fund of valuable information and the general success of the Section to the following officers and members of special committees: George O. Pooley, Chairman; Norton L. Dods, Vice-Chairman; Joseph Bavett, Secretary; Villor P. Williams, Treasurer; A. Bruce Boehm, Chairman, Program-Reception Committee; Edward W. Jahn, Chairman, Membership Committee; and Lawrence F. Magness, Chairman Publicity Committee.

The speakers of the evening in the order of presentation were: W. Lawrence LePage, chief engineer of the Kellett Aircraft Corp.; Earl Bartholomew, director of engineering laboratories, Ethyl Gasoline Corp.; and V. R. Jacobs, assistant aeronautics manager, Goodyear Tire & Rubber Co.

Talks by LePage and Jacobs

Mr. LePage, the new Chairman of the Philadelphia Section, spoke briefly on the Autogiro and its development during the last six years, confining his remarks to the construction and principle of the machine, 72 of which have been produced in the United States in the last eight years, each incorporating an advance in important development work. Tribute was paid by the speaker to Juan de la Cierva, inventor of the Autogiro, for his unfailing belief in the ultimate success of the machine and

its principle despite the ridicule that surrounded the early flights in Europe.

Mr. Jacobs talked of the progress of lighter-than-air craft and contributed a large share toward creating the spirit of conviviality that pervaded the assemblage. Data relating to the world aircraft industry—miles of transport travel in Germany, pounds of mail carried in the Kingdom of Siam, dimensions, lift and cubic capacity of any airship, foreign or American—rolled from his tongue like the water of Niagara.

His brilliant talk was accompanied by motion pictures showing the U.S.S. Akron being built for the Navy Department. The under-construction was photographed while the work of hoisting the giant structures into place was being completed.

Bartholomew Discusses Engines and Fuels

Mr. Bartholomew presented some of the problems connected with the development of high-compression engines and fuels, work which is being carried on by the Ethyl engineering laboratories. A series of slides set forth graphic charts illustrating performance characteristics of different fuels in certain types of engine. The speaker said in part:

Great strides have been made in the study of the mechanism of combustion and we are beginning to have some conception of what happens when fuel is burned in an engine. Within a few years antiknock value has become the most important characteristic of gasoline, and today the price of gasoline is based on this value.

Accurate prediction of actual thermal efficiencies of engines on the basis of theory alone is almost impossible because of the large number of variables that influence the efficiency of a given engine. A combination of experience and thermodynamic theory, however, makes possible exceedingly accurate prediction of the performance of any engine even before it has been built.

If the performance of an engine at a given compression-ratio is known, experience indicates that its performance at other ratios can be calculated quite accurately by a consideration of air-cycle efficiencies for similar conditions. The actual thermal efficiency at two different ratios is in almost exact proportion to the thermal efficiency of ideal air-cycles of the same compression ratios. For example, a certain Otto-cycle engine at 5:1 compression-ratio is known to have an output of 75 hp. and its probable output at 6:1 compression-ratio is desired. The thermal efficiency of an Otto-cycle at a 5:1 ratio is 47.47 per cent, while the efficiency of the same cycle at 6:1 ratio is 51.16 per cent. The ratio of the latter to the former is 1.078. The 75-hp. output of the actual engine at 5:1 may be multiplied by 1.078 to determine the probable output at a 6:1 compression-ratio. This is found to be 80.46.

Pure benzol is commonly believed to be a high-grade antiknock fuel but it has been made to detonate violently in multicylinder automobile engines by failure to provide adequate engine cooling. Even at temperatures substantially below that for preignition, the knocking tendency with a given fuel can be considerably reduced by better cooling, resulting in a consequent higher permissible power output.

The higher the compression ratio of a given engine is, the cooler is its operation. Obviously, if a larger percentage of the heat units in the fuel is converted into useful work in the higher-compression engine, a smaller percentage remains to be dissipated as waste heat. The exhaust valve, which is the hardest worked and therefore the weakest element in all engines, runs at lower temperatures in high-compression engines.

The greatest technical problem confronting the oil refiner is the manufacture of gasoline of sufficiently high antiknock value to meet the needs of automotive engines of constantly increasing compression-pressures.

Light Alloys in Aircraft

Wichita Section Told of Properties of Aluminum and Magnesium Alloys

MAGNESIUM alloy certainly has characteristics that cannot be ignored by designers of metal airplanes, asserted Paul Thornton, of the Kansas City office of the Aluminum Co. of America, in an address at the Wichita Section's last meeting of the season, which was held on May 8 at the Green Parrot Inn. The talk dealt with properties of both aluminum and magnesium alloys that should be given consideration when designing metal airplanes, and the speaker also spoke at some length about riveting. Lively discussion that was both interesting and instructive followed.

H. Fletcher Brown presided as Chairman and new officers for next season were elected. The new Governing Board will take over the reins next October.

Although the aluminum alloy known as 17ST is the one most used, said Mr. Thornton, 51S and 25S are superior in corrosion resistance, the former of these having better resistance when used in the W or quenched condition. Alclad, which is the 17S alloy thinly covered on both sides with pure aluminum, is perhaps the best corrosion-resisting material.

While this Country has been reluctant to accept magnesium alloy, other countries are forging ahead and Germany has brought out an alloy marketed as Elektron. Although this has its drawbacks, its weight is only two-thirds that of aluminum. The strength-weight ratio of magnesium alloys is considerably higher than that of aluminum alloys, including the heat-treatable alloys.

Magnesium alloy has been perfected by the company which the speaker represents to the extent that it will resist corrosion from the elements except that it is corroded by salt water. This can be overcome, however, by a protective coating, such as a good water-resisting spar varnish in which aluminum bronze powder is incorporated. This powder, being opaque, prevents penetration of the actinic rays of sunlight into the varnish, thereby preserving the varnish and protecting the underlying surface.

When riveting the trailing edge of an airfoil section where Alclad is used, said Mr. Thornton, the use of softer rivets would perhaps be better than to use hardened rivets, and the process would be facilitated by placing a thin strip of metal between the two sheets forming the skin, which might overcome the tendency of the rivets to crush the thin sheets.

Stroboglow and Highways Interest Cleveland Section

AN AUTOMOBILE engine valve jumping up and down more than 1000 times per min. was made to appear standing still at the May 11 meeting of the Cleveland Section. The highways of Cuyahoga County were discussed by Dr. J. Gordon McKay, director of the Cleveland Highway Research Bureau. New officers for the 1931-1932 Section year were installed as follows: Chairman, C. F. Oestermeyer; Vice-Chairman, Dale S. Cole; Secretary, Hoy Stevens; and Treasurer, Walter Howard.

Nearly one hundred members and guests enjoyed the last meeting of the season, one of the features of which was the presence as guests of the Section of Majors Johnson, Kelly and Crowley and Captain Ladd, who were passing through Cleveland with a convoy of the Quartermaster Department Motor Transport School from Camp Holabird, Md., to celebrate "Past-Chairman's Night." Also present were eight of the past Chairmen of the Section: J. C. Harron, A. J. Scaife, R. J. Nightingale, O. A. Parker, Clyde Pelton, S. L. Bradley, F. Jehle and Dale Cole. Parlor golf and deck tennis, as provided by Chairman Walter Howard, of the Pre-Entertainment Committee, were enjoyed by a number of the members.

Local Traffic Needs Paramount

In a talk which held the close attention of the members and guests, Doctor McKay described the improvements soon to be made in Cuyahoga County highways. Scientific methods have been developed, he said, for building highways to meet the needs of the future. Local traffic should receive primary consideration, since 80 per cent of the passenger-cars make trips

of 60 miles or less, while 85 per cent of the truck movement covers 25 miles or less. Los Angeles County, Calif., and Wayne County, Mich., have paid a very heavy and unnecessary price for wide arteries that will not be required for many years.

Discussing congestion in city streets, Doctor McKay indicated that no-parking laws are a poor remedy. Of the cause of delay, intersections accounted for 82 per cent, while only 18 per cent occurred in the middle of the block. Of the latter, 10 per cent were unavoidable or not influenced by parking. The real remedy, said the speaker, is to speed up traffic at intersections, as by widening the space available for moving vehicles.

Quarles Explains the Stroboglow

The close-up of the engine valve was secured by means of a grid glow-tube, demonstrated as part of a paper by L. R. Quarles, of the Westinghouse Electric & Mfg. Co., with James H. Herron, first Chairman of the Cleveland Section, presiding. Mr. Quarles explained the working of a device known as the Stroboglow, which was developed to observe whirling airplane-propellers and detect cracks or quivers that do not appear when they are standing still. Other uses, as outlined by Mr. Quarles, are the study of whipping shafts, oil films and spring mechanisms.

The Stroboglow gives off a flashing light, the flashes lasting only 1/3,000,000th of a second. By making these flashes correspond to the speed of a moving part, the part appears to be standing still. The current to produce the short brilliant flash is nearly 1000 amp., according to Mr. Quarles. As averaged by the eye, the effect is of an apparently still object with a pleasing yellowish-red illumination.

Combustion and Carbon Are Considered at Chicago

TWO INTERESTING and informative papers were presented at the last meeting of the season of the Chicago Section, which was attended by 112 members and was one of the most successful of the year. The speakers were J. O. Eisinger, whose topic was Factors Controlling Engine Carbon Formation, and A. H. Vance, who spoke on The Exhaust-Gas Problem.

An excellent squab-chicken dinner and entertainment consisting of boxing bouts and a ventriloquist act in which many amusing jokes were cracked at the expense of the engineers put all in a good humor. A guest of the evening was General Manager J. A. C. Warner, who spoke briefly on the subject of Section activities.

Following the delivery of the papers, Chairman E. W. Stewart introduced the Chairman-Elect and asked him to preside during the discussion. At the close of the meeting a note of thanks was given to the retiring Chairman for his work during the season just ended and also to the two speakers of the evening.

Carbon Related to Volatility

Mr. Eisinger, in his address, said in part that the Conradson carbon-residue test is the generally accepted method of predicting the quantity of carbon that an oil will deposit in an engine. Belief in the reliability of this method has been greatly influenced by the work of the Mellon Institute of Industrial Research, which has made a notable contribution to this rather neglected subject. However, the results of tests that have been made during a period of about two years show that virtually no such relationship exists when comparing oils that have run for 50 hr. in an engine under fairly heavy load and rather high speed. Therefore some property of the oil that is not revealed clearly by the carbon-residue test was thought to be responsible for the carbon deposition.

After due study, volatility of the oil was found to be the primary factor, and a laboratory method was developed for indicating the total volatility of an oil. An excellent carbonization index was found to be the temperature of the 90-per cent distilled point at a pressure of 1 mm. of mercury, absolute, as a linear relation exists between this temperature and the quantity of carbon deposited.

Other data were presented to show the effect on carbon deposition of oil consumption, engine load and length of time of operation.

Room for Combustion Improvement

Speaking of the exhaust-gas problem, Mr. Vance described the chemical reactions that occur during combustion in an engine and the gases that are formed by complete and incomplete combustion. Harmless water-vapor and carbon dioxide are formed by complete burning of the mixture, whereas incomplete burning results in the combination of one atom of carbon with one of oxygen, producing the deadly carbon monoxide. Presence of this in the exhaust represents a loss of power and waste of fuel proportional to the percentage of CO in the exhaust.

Mr. Vance explained various methods used in taking samples of the exhaust and of analyzing them and showed that plenty of opportunity exists for improvement in the burning of fuels.

Race Cars and Combustion

Three Good Papers Interest 350 Attendants at Detroit Section's Closing Meeting

WITH 350 in attendance, the Detroit Section brought its 1930-1931 season to a close with a meeting on May 11 at which new officers were elected a handsome leather golf bag was presented to Chairman P. J. Kent by the retiring Governing Board and three interesting papers were presented. The officers elected for the coming season were announced as follows:

Chairman, O. T. Kreusser, in charge of engineering tests, Fisher Body Corp.

Secretary, George Allen, chief engineer, Dodge Bros. Corp.

Treasurer, F. W. Marschner, western sales manager, New Departure Mfg. Co.

Vice-Chairman, representing Passenger-Car Activity, E. S. MacPherson, assistant chief engineer, Hupp Motor Car Corp.

Vice-Chairman representing Body Activity, Roy F. Anderson, sales engineer, Murray Corp. of America

Vice-Chairman, representing Aeronautic Activity, W. S. Pritchard, factory manager, Detroit Aircraft Corp.

Vice-Chairman, representing Student Activity, Alex Taub, research engineer, Chevrolet Motor Co.

Fred S. Duesenberg gave a paper in which he discussed the rules for the 1931 Indianapolis Race and described the cars entered in it. He pointed out that the rules required that all cars must have a minimum weight of 1750 lb. and weigh not less than 7½ lb. per cu. in. of piston displacement, which meant that a 100-cu. in. engine must drive 17½ lb. per cu. in., while a 233-cu. in. engine driving 7½ lb. per cu. in. could qualify. Only one entry had a 233-cu. in. engine, and this seemed to be a Hudson. The largest displacement was that of the Coleman, a front-drive car with eight-cylinder engine of 364 cu. in. which required a weight of 2730 lb.

The entries included six front-wheel-drive cars and the rest appeared from the entry blanks to be rear-drive cars. Three or more cars with independently sprung rear wheels were entered, being listed in the class for new professional cars. Another newcomer was the Cummins Diesel-engined car, which is of Duesenberg frame and axle construction and weighs 3150 lb. This is the car that made a straightaway record of 101 m.p.h. on the Florida beach last winter. In the professional class for cars built for the Indian-

(*Continued on page* 693)

Chronicle and Comment

Milwaukee Famous SEVERAL hundred production men are still talking about the many excellent features of the Production Meeting that was recently held in Milwaukee under the joint auspices of the Milwaukee Section and the Production Activity Committee of the Society. Chairman Frantz, together with other officers and members of the Milwaukee Section, is deserving of warm congratulations for the outstanding success of this affair. Vice-President A. K. Brumbaugh, of the Production Activity, and Joseph Geschelin, Chairman of the Production Activity Meetings Committee, are also to be commended for the part performed by the Production Activity in making the Milwaukee Meeting of such great benefit to our production members.

More than 300 persons attended one of the technical sessions, and the three inspection visits to Milwaukee plants were enjoyed by a large majority of those present at the meeting. These visits to the plants of A. O. Smith, the Kearney & Trecker Corp., and the Hevi-Duty Electric Co. were unusually well organized.

For example, at Kearney & Trecker, the members were divided into small groups, to each of which a guide was assigned. Along the route, which was well marked with arrows, the visitors were shown various machines of different types in operation. Finally, at the end of the route, the several parties gathered around a number of machines that were processing material at very high speeds by the use of tungsten-carbide tools. At each of these stations a loud speaker was located, and an expert, seated on a perch above the visitors, could clearly be heard as he described the process that was being witnessed. Everyone was able to see and hear, an unusual feature of plant visits.

It is understood that the precision and smoothness of this particular visit was due in large measure to the fact that the whole affair had been rehearsed the night before, with several score of employes impersonating the interested S.A.E. members.

Mr. Kearney and Mr. Trecker were there in person to welcome the visitors.

Measuring the Knocking Tendency A task of no mean proportions was that imposed upon a small group of men appointed in February, 1928, by the Cooperative Fuel-Research Steering Committee to bring order out of chaos in the field of measuring the knocking tendency of gasoline. This group, officially known as the Subcommittee on Methods of Measuring Detonation, analyzed the problem and agreed at the outset that the first undertaking should be the development of a scientific instrument for use in measuring the detonating quality of motor gasoline; the second phase of the problem, the determination of a method of making knock ratings that would be universally acceptable. At the inception of this research, the laboratories of no two companies were using the same method of knock measurement; yet no one had sufficient confidence in the infallibility of his procedure to promote it as *the* method worthy of standardization.

Before the Committee could even begin to judge the relative merits of methods, a common language for expressing antiknock results had to be worked out and adopted. The standardization of octane numbers, established as S.A.E. Recommended Practice in January, 1931, is the Committee's answer to this problem.

The papers presented in the Detonation Symposium at the Society's 1931 Annual Meeting, the first installment of which is printed elsewhere in this issue, show that much has been added to specific knowledge on the effect of engine factors on knock rating.

Commendable indeed is the courage of this group which, in spite of the fact that the members are poignantly aware of the great ignorance which still obtains on many factors in detonation testing, has come to the rescue of both petroleum and automotive industries with a tentative procedure for conducting knock tests.

This method will, of course, be subject to rapid and continuous change, but surely, however slowly, the user of gasoline is arriving at that Elysium in which at least two properties can be intelligently specified. The results of the Steering Committee's excellent research on volatility have already been universally accepted.

Meanwhile, the design of the knock-testing engine is progressing by a rapid evolution wherein but one more concerted effort remains to produce a finished product.

Dividends Guaranteed IDEAS and technical information of immediate value to individuals and the companies they represent; contacts that broaden, develop new thought and promote understanding; acquaintanceships that stimulate a spirit of cooperation; a refreshed viewpoint and a renewal of vigor for the industrial grind; a chance to get the boys out of the ruts before fall—these are among the dividends that are guaranteed from an investment of a few days and a few dollars spent upon the S.A.E. Summer Meeting. These dividends are bigger than the original investment, and are payable immediately for reinvestment in a great industry.

Standards Committee Reports Ready THE Reports of Divisions of the Standards Committee that will be considered at the Standards Committee meeting at White Sulphur Springs, June 17, comprise 27 reports by 7 Divisions which are printed in Section 2 of this issue of THE JOURNAL. Of these reports 10 are new subjects for original adoption, 15 are revisions or extensions of existing standards and 2 are cancellations of obsolete specifications.

The report by the Motorcoach and Motor-Truck Division on Uniform Vehicle-Operating-Cost Classification is a somewhat new type of recommendation for adoption by the Society, in that it relates to engineering economics in motor-vehicle fleet operation. The report was developed by the Transportation and Maintenance Activity Committee over a period of nearly six years.

A number of important subjects, among which are airplane-propeller mountings, airplane-engine carbureter mountings, Diesel-engine fittings and valves, and a broad study of fine screw-thread pitches in diameters larger than 1½ in., are in progress, on which it is hoped definite recommendations will be completed for the Annual Meeting next January.

Rubber Problems *Confronting the Automotive Engineer*

By R. K. Lee[1]

Annual Meeting Paper

SO MANY different rubber parts are used in present-day automobiles and the variety of rubber specifications is so great that the author believes this material should be given consideration in the engineering departments commensurate with its importance and that the problems of design and specification of rubber parts should be analyzed in the same way as are those of the other components of the car. He points out that, while the engineer can turn to reference books and choose with certainty a metal of standard quality that will meet the requirement for a particular design and purpose, he does not feel safe in specifying a quality of rubber stock or a design to meet given requirements and that can be made in the best and most economical way.

A list of equipment regarded as necessary and sufcient for carrying on intelligent rubber-engineering investigation is given and the conditions and properties that have been found important in the choice of rubber stocks are listed. The author then illustrates the findings during four years' work in the Chrysler Corp. rubber laboratory by giving examples of the choice of testable physical properties of rubber that will meet the requirements of specific parts.

Various tests and their results are discussed and the suitability of certain properties for given uses or the problems presented by them are explained. Considerable emphasis is laid on the importance of rubber manufacture procedure and of designing rubber parts, some outstanding examples being given of what not to do when designing shapes for molds. Considerable time and money can be saved in ways pointed out without adversely affecting the functioning of the part.

In contributed discussion a Foreign Member in England lists a large number of possible applications of rubber to cars, many of which are in use abroad while others proposed seem radical.

SOME FACTS concerning the importance of rubber in the automobile industry are: In the Chrysler Corp. we have over 650 different rubber parts and 88 different rubber specifications. In the Chrysler 8 sedan there are 270 individual rubber parts; total weight of rubber parts, 141 lb.; 3.8 per cent of the total weight of the car; mechanical rubber parts, 38 lb.; and approximately 8 per cent of the total cost of the car is in rubber.

With these facts in mind, I believe we should give this material its proper place in our engineering departments and analyze the problems of design and specification of rubber parts in the same manner that we do other components of the car.

When a designer draws up the design for a metal part for the car he immediately asks himself what is required of the part in the way of stresses, how many per car unit are to be made, what build-up of dimensions is necessary, what relation exists between function of part and cost, and many other factors which will be extremely important in making his choice of materials, finish, and so on.

In metal parts we have established a precedent of both design and quality over a period of years which enables us to turn to our reference books and immediately, without fear or hesitation, choose a standard material that will meet the particular requirement, then shape the part in a design which can easily be made according to the best practice known to the industry.

When a choice of these qualities in rubber is necessary, how many of us feel absolutely safe in specifying a quality of rubber stock or a design which will meet the requirements of the car and which may be made in the best manner possible?

Some years ago this problem was turned over to me and I readily came to the conclusion that I knew absolutely nothing about this material. Through the generosity of Mr. Chrysler and our engineering executives, I was permitted to equip a rubber laboratory which would enable me to find out such information as was required by our engineering department in designing our rubber parts and also in specifying the quality of rubber so that the purchasing department would be able to buy from the specifications a rubber stock of a quality which, in production, would be similar to the original engineering part.

The following information is not meant to be taken as a standard to follow in your engineering rubber problems, but is given as some definite examples of things we have done and results we have obtained. If it merely starts a small percentage of my engineering associates to thinking along the lines of rubber developments and the advantages of such work I shall consider myself amply repaid.

At this time, I want to thank the rubber manufacturers for their cooperation and will say that I have received the most courteous treatment and help from them. I also know that, if you would cultivate engineering contacts with them, they would be glad to help you in any of your own rubber problems.

[1] Director of research, Chrysler Corp., Detroit.

Equipment Needed in a Rubber Laboratory

First, I desire to show and explain the equipment at the Chrysler laboratory, which I consider necessary and sufficient to carry on intelligent rubber engineering work. The photographs reproduced in Figs. 1 and 2 were taken some time ago and do not include all of the equipment in our laboratory at the present time, so I will itemize the complete set-up:

Two 24 x 24-in. hydraulic presses
1500-lb.-per-sq.-in. steam-driven water-pump
Open-cure heater
Masticator-type cement mixer
Scott rubber-tensile machine
Olsen tensile machine
10 x 24-in. mill, with 10-hp. motor
Two DeKotinsky aging ovens
Ultra-violet-ray aging light
Cold-room tensile machine
Cold-flow test equipment
Abrasion-test machine
Chemical balance
Accurate temperature-recording and control apparatus
Fatigue-test equipment
Electroplating equipment
Tensile-strip-cutting fixture
Chemical and rubber-storage metal bins
Electric ball-mill

To give an idea of the volume of work done in the laboratory, we use approximately 3000 lb. of crude rubber per year. All rubber parts for experimental and new-model cars are made from our molds in our laboratory. We find a decided advantage in working the design and qualities out first in our laboratory over the practice of having a specific rubber company spending its money for the molds and experimenting. In this way the rubber companies all have the same standing with the purchasing department at the time of buying.

Through contacts with the rubber companies and tests run in the laboratory, we find that, in the rubber parts we are using in the car, we have stocks ranging from 500 to 5000-lb. per sq. in. tensile strength, 200 to 800-per cent elongation, 1.1 to 5 specific gravity, 2 to 70-per cent crude rubber, and from 8 to 80 cents per lb. Our problem, then, is to be able to choose the right compound for a specific place.

Following is a list of conditions which we have found important in connection with this choice of rubber qualities or stocks:

Temperatures and fixed compression-loads
Abrasion
Mechanical deflection or deformation
Proportions between movement and volume
Appearance or finish
Chemical reactions on rubber and of rubber on other parts
Manufacturing procedure
Dimensional variations
Change of physical properties due to aging

Going over these items roughly, I will illustrate our findings by giving examples, wherever possible, of our choice of testable physical properties of rubber which will meet the particular-part requirement.

Temperatures and Fixed Compression-Loads

A test was run in a "hot room" on a Plymouth car running at 35 m.p.h. at an air temperature of 115 deg. fahr. over a period of time sufficient to permit the temperatures of all parts of the car to become constant, with the equivalent of a 20-m.p.h. wind, for the purpose of finding out just what temperatures were reached in the rubber parts. Some of these temperatures are:

	Temperature, Deg. Fahr.
Running-Board Mat	152
Floor-Board Mat, front	153
Floor-Board Mat, rear	142
Body Shim, front	160
Hood Corner, front	137
Hood Corner, rear	150
Dash Grommets	135
Engine Mounting, front	157
Engine Mounting, rear	161
Fan Belt	172
Duffey Pads	150
Distributor Leads	160
Spark-Plug Leads	167

The demands for certain parts made of rubber to maintain their original shape when subjected to pressure and temperature forced the exploitation of this comparatively new property of rubber; or, rather, the extent of change in shape had to be greatly reduced over all previous stocks. The term adopted for this characteristic is "cold flow" or "flow." It relates to permanent set, but, since this term had usually been associated with the tensile and elongation permanent deformations, this term was selected to indicate the compression flow.

As the mere specification of high quality does not assure good non-cold-flow properties, it is necessary that the laboratory have some means to evaluate cold flow. The following test was originated by C. Bockius, of the Manhattan Rubber Co., and seems to answer this problem very well. By means of a spring-pressure device which is self-contained and may be placed in the aging oven, a disc of rubber ¼ in. thick and ¾ in. in diameter is subjected to a pressure of 600 lb. per sq. in. at a temperature of 158 deg. fahr. for 24 hr., the percentage of cold flow being the change in thickness divided by the original thickness. To give an idea of the amount of permanent set or cold flow and the change in extent of set brought about by this investigation, when we first started this test at the Chrysler laboratory four years ago it was not possible to get more than one or two of the rubber companies to consistently submit samples of rubber under 20 per cent. Today we can get in production from a number of companies rubber which will run under 6-per cent cold-flow.

We know that, when we keep the pressures on rubber of a specified quality down below 25 lb. per sq. in. and the temperature below 158 deg. fahr., the part being free from the action of oil or other destructive chemicals, we can expect a rubber having a tensile strength of 2000 to 2500 lb. per sq. in., hardness from 40 to 60 Shore Durometer, and a cold flow of 15 to 20 per cent, to hold its dimensions within close limits over a period of three to four years.

When these conditions of temperature and pressure are exceeded, we must use a much better grade of rubber and should analyze each problem separately and carefully. The physical properties which should guide the choice of stocks in these cases should include tensile strength, elongation, cold flow, hardness, aging due to heat and ultra-violet rays, modulus, and permanent set in elongation.

Some rubber companies doubt the necessity of high-tensile specification on compression stocks, but we have found that specifying a tensile strength of more than 3000 lb. per sq. in. usually assures a much better grade

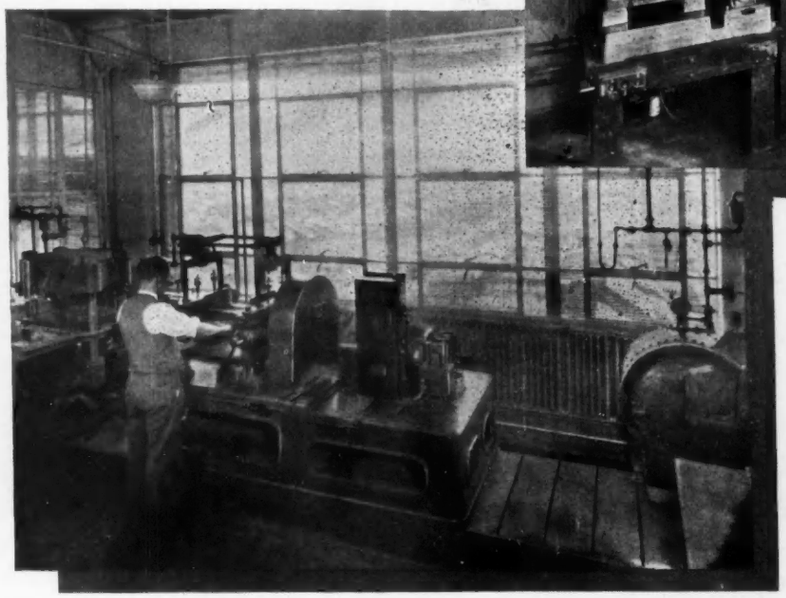
of stock, containing a higher percentage of new rubber than if 2000 lb. or less is specified. This does not mean that some of the compounds containing reclaimed rubber are not good stocks. This is illustrated by the fact that, now that the price of rubber is 10 cents and less per pound, all of the rubber companies continue the use of reclaims which cost just as much as new rubber and get a quality that is impossible to duplicate in stocks using 100 per cent of new rubber.

Where a stock is subjected to a temperature of 200 deg. fahr. but no pressure, a test should be arranged wherein the elongation before and after aging in the open oven should guide the selection of stocks, depending on the nature of the stresses on the part.

Where a change in physical properties due to low temperatures affects the functioning of the piece, limits of change should be established. In connection with this property of rubber, we have been able by compounding to effect a difference of more than 50 per cent in the force necessary to deflect rubber a given distance at 0 deg. fahr. for the same burdens.

Abrasion

Parts such as mats and step pads should be considered with respect to abrasion. About the only way we have found to satisfactorily test abrasion is to compare the condition of samples of materials placed on a stairway in the factory where there is considerable use. We purchased and built several abrasion-testing machines but, in my opinion, the conditions in the machines are so different from those in service that there is a great question as to their worth. A point that should be considered along with abrasion is that of the design or the figure of mats. We have found that designs having an irregular embossed surface show the effects of abrasion, for the same volume of material worn from the mat, much sooner than the plain regular-stripe designs.



FIGS. 1 AND 2—SOME OF THE EQUIPMENT USED IN THE CHRYSLER CORP. RUBBER LABORATORY

If a part must be subjected in service to continued deformation, extreme care should be taken to prevent localized strains, just as in steel or other manufacturing materials. Also, localized abrasions are frequent and harmful. A set-up should be made to approximate actual conditions and, if possible, to interpret car-miles into deflections. Load-deflection curves should be made before and after test, since rubber may have a localized fatigue-failure yet, from outward appearance, still be in good condition. These failures usually show up in the load-deflection curves. Up to the present, we have found it unsatisfactory to deflect rubber over 100-per cent elongation in continuous tests or applications. When we go over 100 deflections per minute, there is considerable chance of internal heat causing trouble.

An example of the working out of continued deflection of rubber under compression is the Silent-Bloc spring-shackle. When this bushing was submitted to us, we had considerable trouble getting over 5000 miles on test cars without replacing bushings. We found that the unit pressures on the bushings were extremely high and the deflections out of proportion to the volume of rubber used. As soon as these properties were corrected, the life was so greatly extended that it is impossible, under ordinary circumstances, to wear out the bushing in the life of the car. The laboratory equipment in this case consisted of deflection-measuring equipment and oscillating equipment, shown in Fig. 3, in which it was possible to vary the load and deflection on each bushing.

An interesting interpretation of oscillations into car-miles was made possible by the indicator shown at the lower right in Fig. 3. The body of the instrument is attached to the frame of the car over the axle, and the arm is joined to the axle through a swivel joint. Three indicators are geared to the pivot of the arm in such a way as to record the total angular movement of the arm, which may be translated into shackle movement, in one indicator, each oscillation in another, and all over a se-

lected angle on the other indicator. Thus it was possible to go out on various roads in any car and actually measure over a distance of miles the exact work the shackle must stand.

On one test run of 966 miles over Michigan, Indiana and Ohio roads, with a five-passenger load, the indicator showed a total of 108,300 in. of axle movement. This is approximately 112 in. of axle movement, or 66 deg. shackle movement, per mile on the rear-spring maximum-angle shackle. On the laboratory test, after 1,218,000 oscillations, the bushings are still in usable condition. This represents 217,000 miles on the car. The tests are run at 90 oscillations per minute. On test cars, after 80,000 miles, the bushings are in excellent condition, which shows us that we are not far off in our laboratory tests.

A similar test was set up on engine mountings but, owing to the small amplitude of movement in the car and the enormous factor of safety in the adhesion mountings on our cars, the test ran over 10,000,000 oscillations over a period of two years. At the end of that time the deflection rate had not changed within the limits of reading the instruments and there were no noticeable fatigue signs, so the test was abandoned.

Another interesting test that is conducted along the same lines is the spring-bumper test, in which a hammer is raised and tripped and allowed to drop a given distance, striking on the spring bumper. The difference in the effects of this test on the various standard spring-bumper stocks in production by the various rubber companies is surprising.

Modulus Specified by Deflection Rate

As it is possible in rubber parts to have the correct hardness, tensile strength and other physical properties and still have a different deflection rate due to a change in modulus, it is sometimes necessary to specify modulus. This may be done in some cases by specifying a definite limit of deflection rate, in pounds per inch of deflection. Where an engine-mounting build-up rate determines a torque period, a special test-fixture is made for production which will weigh, with respect to deflection rate, each mounting or a definite percentage of the production parts. In cases of this kind, the rubber company must be instructed to watch the curing time more carefully than in standard practice and, if the part is extremely critical, the vendor should make a similar test fixture in his plant and watch the control from day to day, since the variation in climatic conditions is sufficient to change the modulus and cold-flow properties more than the specified limits.

Shrinkage sometimes gives the same effect as a change in modulus, especially where rubber is bonded to metal. This is because, if the rubber is confined to a fixed volume in curing, the shrinkage of the rubber places it under a tension which will change the build-up rate of the mounting. To avoid this difficulty, clearance is left between the metal parts when in the mold according to

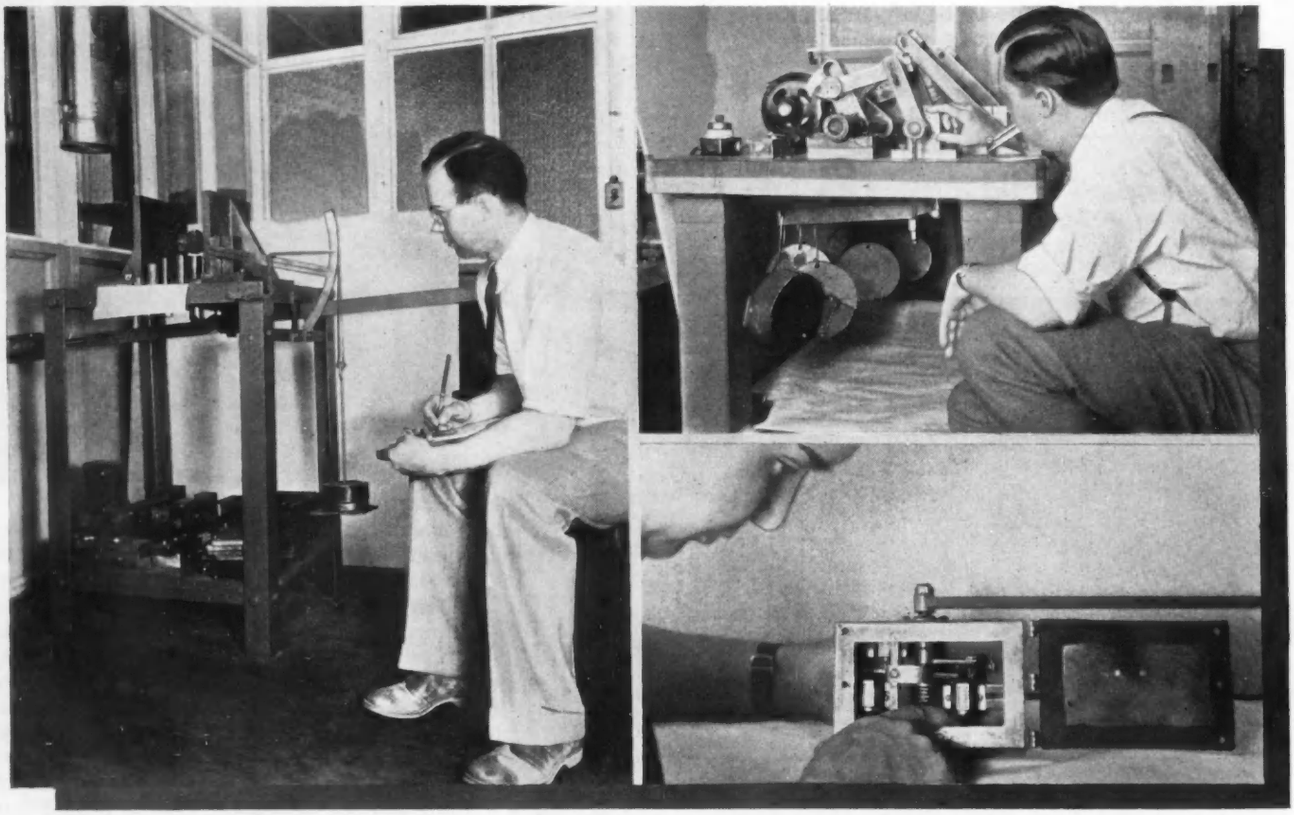


FIG. 3—APPARATUS FOR MAKING VARIOUS TESTS ON RUBBER PARTS

(Left) Fixtures for Measuring Radial and Endwise Deflections of Rubber Bushings. (Upper Right) Making a Life Test on Bushings. (Lower Right) Shackle-Angle Indicator Which Is Attached to the Frame of a Car with the Arm Joined to the Axle and Measures the Work Done by the Shackle per Mile

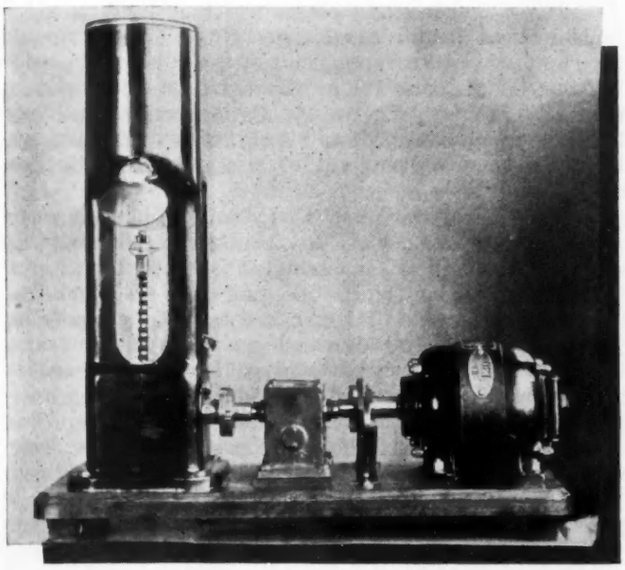


FIG. 4—RUBBER TENSILE-STRENGTH TEST MACHINE FOR USE IN THE COLD ROOM

the volume of rubber involved and, when cooled, the rubber can be restored to a normal condition by taking up this clearance.

To make an accurate study of the change in modulus, a special automatic stress-strain tensile machine was designed so that it would be possible to study the characteristics of deflection in the same machine under various conditions of temperature. This machine can be taken into the icebox or cold room and plugged into the light-switch circuit so that the observer can be outside of the box and observe through glass windows the indicators of the machine throughout the complete tensile cycle. This is particularly adapted to small refrigerator units of the lower-temperature type. The sample is placed in the tensile jaws, which are adapted to be separated by means of an electric motor through a gear reduction, the tensile pull being registered on a calibrated spring in the head of the machine, which is shown in Fig. 4.

Proportions Between Movements and Volumes

Where rubber is relied upon to give a certain deflection rate, the proportions between amplitude of movement, pounds per square inch of load and volumes of rubber are very important. This problem arises in the designing of engine mountings to have the same deflection rate for engines of different weights. I have found it advisable to proportion thickness or volume of rubber almost entirely according to the vibration amplitudes of the engine and the area in tension according to the weight of the engine. Many other factors, such as frame rigidity and engine bounce, enter into this problem, making impossible the laying down of any fixed rules for proportions.

In the case where rubber is confined between two moving parts, the volume of rubber must be sufficient that, in the elongation of the rubber due to movement, there should be no localized sections where the stresses exceed the capacity of the particular stock. Also, where the rubber is under compression between moving parts, the volume should be sufficient that deflection be all within the rubber instead of on the surfaces of contact. In designing rubber parts such as those in clutch members and vibration dampers, it should be remembered that rubber is incompressible and therefore is adapted only to flow, and where this flow is appreciable it must be remembered that the rubber must stretch just the same as in the tensile machine, causing fatigue spots or cracks on the body of the rubber, which in turn cause abrasion, resulting in heat and destruction.

Can Reduce Cost in Specifying Appearance

Wherever a piece is exposed in the car assembly, special attention of the rubber company should be called to this instead of making more or less uniform appearance requirements for all rubber parts. Trimming and buffing in the factory of the rubber company are the most expensive operations of all, since most of this work is done by hand at a high overhead rate. To give a comparison with other types of work, a pressman may take care of two or three presses each holding up to 10 molds, which in small-part work may have up to 100 cavities each. The molds usually are rotated in such a way that the operator is tripping and filling one set of molds while the other molds are in the press, making possible a very low overhead. In trimming and buffing, it is evident that each part must be handled separately by the operator and, while the hourly rate of this help is somewhat lower than that of the pressman, the cost of this operation greatly exceeds the molding costs. Therefore, except where the part is exposed, it is desirable to make as little mention of appearance as possible.

Chemical Reactions and Rubber

Care should be taken in the placing of rubber parts that an excess of oil or gasoline is not present. Some of the rubber companies can furnish a rubber stock that is almost completely oil-resistant, but this stock will stand only about 10 per cent of the deflection and tensile test of a good grade of high-rubber-content stock. Therefore, where any particularly high physical requirements are necessary it is not advisable to specify rubber parts for use in the presence of oil.

FIG. 5—MACHINE FOR EXTRUDING RUBBER TUBE UP TO 16-IN. DIAMETER AND OF ANY DESIRED WALL SECTION

This Is of the Hand-Fed and Conveyed Type Which Has Been Replaced in Most Cases by a Fully Automatic Type of Tuber That Measures and Cuts to Length the Extruded Parts Ready for Curing

Oil-resistant qualities should be specified in percentage of change in volume for a given time submerged in a standard grade of mineral oil or kerosene at a given temperature. Temperature will be found to be one of the important factors in this specification.

Another item coming under this heading is the effect of the sulphur contained in rubber upon the polished metal surfaces of hardware, lamps and so on. Where such contacts are made, it is necessary to specify a rubber having a very low sulphur content and, in some cases, containing no sulphur. This is now possible with the aid of new vulcanizing agents developed in the last two years. A sulphide at the point of contact of rubber with steel, especially under pressure, will cause a direct adhesion between the rubber and steel, and, where this is not desirable, we must specify a compound which will not support the forming of this sulphide.

Where a bond is desirable, it is likewise necessary that the rubber company use extreme care in choosing the accelerators and other ingredients for a compound which is best suited for the particular type of bond being used. An excess of sulphur in the form of bloom is sometimes very harmful in connection with the bonding of rubber to steel.

In brass-plating for bonding metals to rubber, extreme care should be taken in the choice of such factors as the copper-zinc content of the brass, the rate of plating, the current density and the acidity of the plating bath.

Surface-blooming of the sulphur in the rubber is sometimes criticized unduly, since we have not been able to prove, and some of the largest rubber companies are in doubt about, the real harm of this sulphur bloom in unexposed rubber parts. There is a slight variation in hardness of the surface of a badly blooming stock but, where this does not affect the functioning of the part, it is sometimes advisable to have a slight excess of sulphur in the compound to prevent the effects of undercuring, which to my mind is more serious than blooming.

Rubber Manufacturing Procedure

This subject in connection with rubber should be exploited much more thoroughly than my time will permit, so I will choose some of the more outstanding examples of what not to do in designing rubber parts and explain some of the steps necessary for their manufacture.

Wrapped Goods.—Radiator hose, cut washers, fan belts and so forth are one of the less expensive types of goods, in most cases; but this does not mean that quality is lacking in any way, the lower cost being due entirely in this case to the lower labor cost.

Tubers or extruders of the type shown in Fig. 5 may extrude a tube of rubber of any dimension or cross-section up to about 16 in. in diameter. The machine shown is a hand-fed and conveyed type which has been replaced in most cases by a fully automatic machine which in some instances measures and cuts to length the extruded parts ready for curing. In the case of radiator hose, the tube forms the inner casing of the hose. It is blown over a mandrel by means of compressed air, the mandrel being the size of the finished inside diameter of the hose. As many plies of fabric or different grades of rubber as desired are then either wrapped or blown around the inner tube, and this assembly is wrapped under pressure with moistened cotton fabric. The shrinkage of the fabric makes an additional pressure when the assembly is heated. This wrapped hose or tube is then placed in an open-cure heater, which is nothing more than a steam heater capable of bringing the temperature up to the vulcanizing point of the rubber and holding this temperature for a sufficient time to completely cure the rubber. The assembly is then taken from the heater, unwrapped and the finished hose blown from the mandrel and cut to size on automatic machines.

In the case of washers, the thickness dimension can be held very close, but, as the outside diameter is wrapped with fabric for curing, it is necessary to give a wide tolerance on the outside diameter. It is possible to grind the outside diameter and hold the dimensions very close, but this adds considerably to the cost and should be avoided whenever possible. Since there is practically no scrap in this operation, it is much cheaper to make washers this way than by stamping them out of cured sheets, where the scrap is sure to be more by weight than the finished articles.

In the case of hydraulic-brake hose, the operations are much more complicated, as it is necessary to braid the cotton around each separate length of hose and wrap the lengths individually for curing. When one considers the bursting strength of the hose and the way the ends are coupled to the hydraulic system, I believe that it will be agreed that this is one of the outstanding developments in recent years in the automotive-rubber field. To maintain a uniform bursting strength, each cord of the braid goes on the hose at a given tension, which in many cases is 60 per cent of the tensile strength of the cord. This cuts down the expansion characteristics to less than 1 cc. volume expansion per length of hose when subjected to a pressure of 1000 lb. per sq. in. Many other important properties and manufacturing methods make this one of the most expensive items in the rubber field, but when it is known that in the last four years we have not had a single failure of hydraulic hose due to bursting in service, it can be seen that the problem is under absolute control, thanks to the concentrated efforts of the development departments of the rubber companies.

Flat or Calendered Goods.—The volume of this type of material makes it one of the most important of the rubber items and, therefore, one which should receive utmost consideration.

One of the outstanding considerations should be the choice of design or figure for the running-board or floorboard mat. You must remember that in making the original mats it is necessary to cut in steel a master plate for each different design. From this master plate, hard-rubber molds are made which are used in production. These molds have a definite shrinkage which changes for each design and rubber compound. It will be noted then that, where you specify borders and cut-outs in the mats and expect the borders around the cut-outs to come exactly in the right place, you are asking considerable from the rubber company in the way of close dimensions. Therefore, wherever possible, borders should be avoided, especially around cut-outs for pedals and the like. It is possible to adjust the borders around the outside of the mat by leaving an excess of stock to be trimmed after molding, but in the center of the mat it is almost impossible to count on 100 per cent of the mats even approximating the dimensions of the drawing.

In choosing the figure of the mat, one should try to picture a design that he could make himself in his tool-

room with the aid of standard tools. Designs having large flat ribs and deep indentations are very difficult to mold, owing to the trouble in getting the compounds to flow evenly into the recesses of the mold. If the large flat designs are desirable, be sure to specify a grade of stock having a much higher tensile strength and elongation than the average running-board stock, since these high-grade stocks flow much more readily than the cheaper ones. In the last year we have improved our grades of stock approximately 30 per cent and recommend that, since these parts are the ones most seen, more care be taken than in the past in choosing stocks.

Where it is necessary to bond a mat to the running-board, we have found it advisable to use 5-oz. burlap in the back of the mat, first, since this permits the rubber company to pull the green stock through the presses with less chance of tearing, and, second, it adds body to the mat material, making the possibility of blisters in the finished running-board less than with a plain rubber since the liquid or flowing condition exists only when the stock is subjected to a temperature of 220 deg. or more and to a high pressure. Since pressure plays an important part in the vulcanizing of the rubber, it will readily be seen that it is necessary to have prepared a slight excess in volume of green rubber to fill the cavity of the mold to avoid porosity. In the higher-grade stocks this is more imperative than in the cheaper grades, since the density and porosity are more critical in the better grades. In some parts such as the inserts for Silent-Bloc, unless the volume and overflow of the stocks are correct, a complete change of physical characteristics results. The change in temperature due to a draft from an open window is sometimes sufficient to throw the outer pieces in the mold completely off. Each different piece must be carefully analyzed from a mold standpoint and designed to cause the least possible trouble in molding.

Two examples will demonstrate the possibilities of the

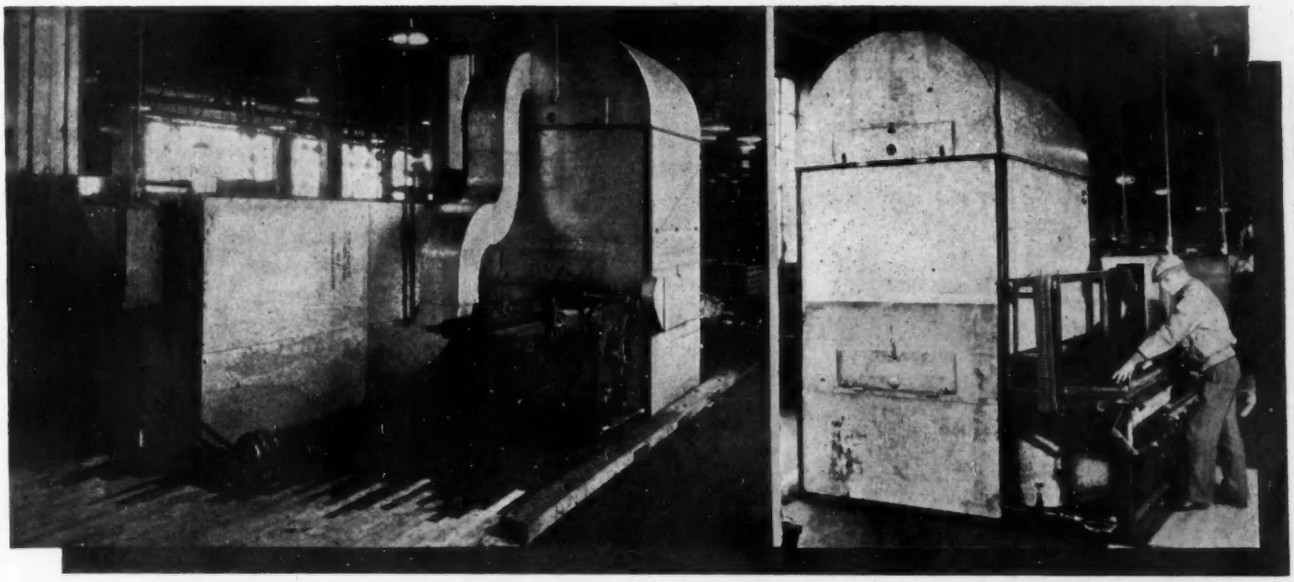


FIG. 6—AUTOMATIC MACHINE DEVELOPED FOR CEMENTING RUBBER MATS TO RUNNING-BOARDS

The Boards and Mats Are Automatically Coated with Cement, Heated from 4 to 5 Min., Assembled Together and Placed in an Air-Bag While Hot, Giving a Uniform Bond. Two Men Can Apply Mats to 2200 Boards in 9 Hr.

mat. We found that, when cementing the mat to the board, it was necessary to apply heat and pressure uniformly to the entire surface of the board to secure the maximum bond. We developed an automatic machine, shown in Fig. 6, for this purpose which would take the human element out of the picture and, by fixed timing and heat controls, make it possible for two men in 9 hr. to apply the mats to 2200 boards, giving a uniform bond which will hold more than the rubber stock itself, at a price very little higher than the cost of the raw materials.

Molded Goods.—This type of material is the most widely used form of rubber and the one which presents the most difficulty in manufacturing. Let us first consider the process of molding so that we shall all understand the steps necessary in this type work.

The raw material has much the same appearance as the finished stock, except that it has virtually no resiliency and no tensile strength. It is necessary, however, to treat it as a fixed solid and not as a liquid, assistance we may be to the rubber manufacturer. The use of fillets in castings is very good practice, but in rubber parts they considerably complicate the mold. Let us consider the case of a straight rubber ferrule or bushing. When we call for radii on the ends of the ferrule, we make it necessary for the mold maker to make a two-piece complicated mold with the radii cut in the top and bottom plates or to sink cavities the full depth of the part in the body of the mold, whereas, if we could do away with the radii, the mold would consist of a straight hole through the middle section of the mold and perfectly flat top and bottom plates or a plain counterbored cavity in the body of the mold, as illustrated in Fig. 7.

For complicated boots or dust covers, it is often necessary to make four or five-piece molds with detachable cores, whereas, if a little care were exercised in design, the mold could be a simple two or three-place mold, as in Fig. 8. The first thing that a designer thinks of is that the rubber company pays for the mold and that

it makes no difference to the consumer, but he must consider that someone must pay for the mold and that, even though it is absorbed in the cost of the parts, the mold is being paid for by the consumer. Remember when designing rubber parts that a cavity must be cut the reverse of the piece to be made, and that the operator must be able to assemble and take apart the mold many times a day, taking the rubber part from it while it is at a temperature of about 300 deg. fahr., and that whatever thickness and outside dimensions the part has, the mold must be enough larger than the piece to assure mold strength and contact surface with the press.

Metal inserts when used must be completely inclosed in the mold so that the heat will penetrate into the metal as well as the rubber. In metal-insert work, especially where a good bond to the metal is required, it is necessary to design the parts so that there is no flowing of the rubber over the surface of the metal parts. For some reason this flowing of rubber greatly weakens the bond, especially in using brass-plating. Where possible, it is desirable to locate the metal parts by having direct metal contact with parts of the mold and, in the case of round flat parts such as vibration-damper parts, we maintain rubber thickness by permitting the top plate to either rest on the bottom of the mold cavity or on locating lugs of the mold. Owing to variations in stampings and in mold cavities, it is desirable to locate the stampings from holes in the stamping, leaving about 1/16-in. clearance completely around the part for clearance in the mold so that the part can be extracted from the mold easily. All of the time the mold is out of the press it is cooling off; consequently, since the heat must flow from the press to the mold, this loss of temperature means dollars in B.t.u.'s lost in cooling and variation in cures. When the parts are hard to remove from the mold and there are a number of cavities in the mold, much lost time and high unit-cost result. As in our own assembly and manufacturing costs, labor and overhead run arm in arm in the rubber plant, so it is likewise important that labor be eliminated wherever possible.

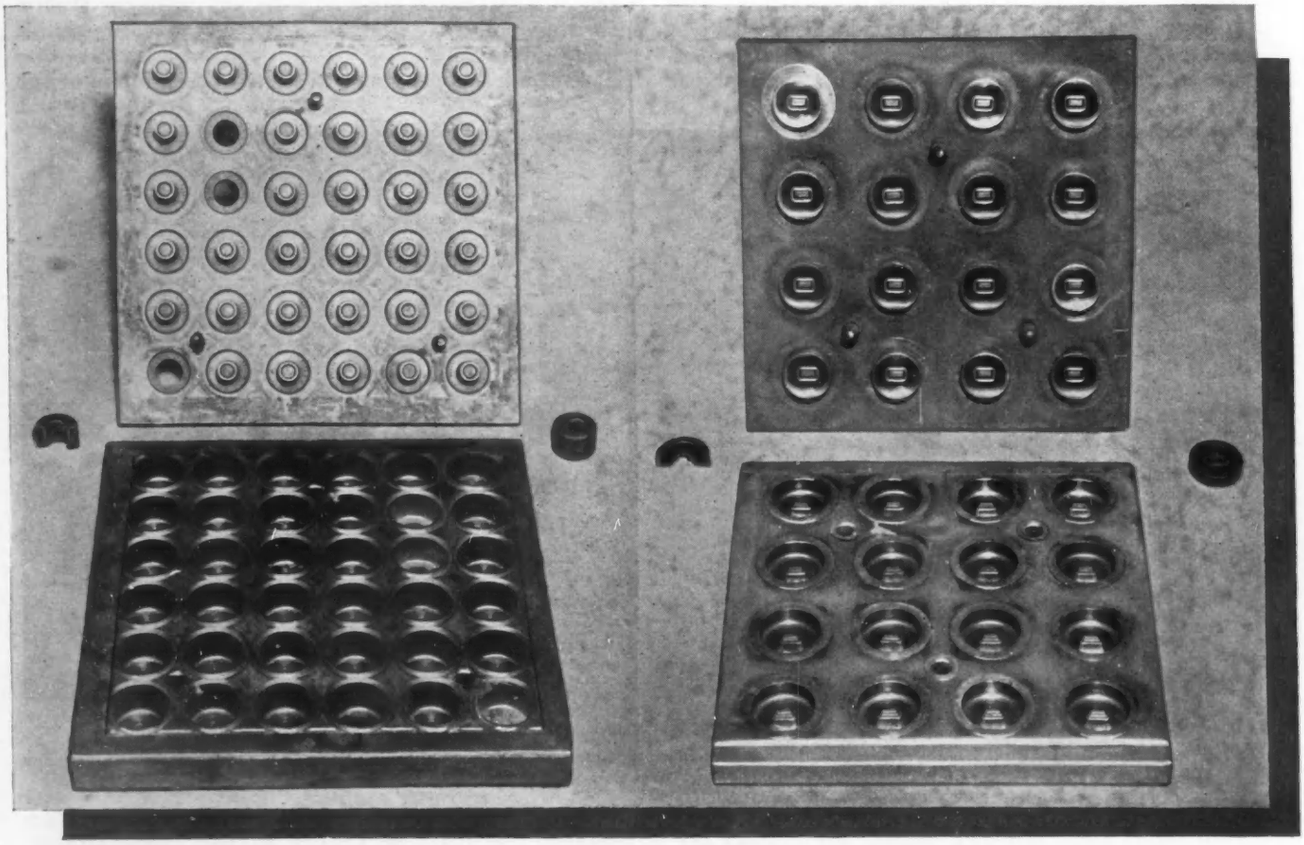


FIG. 7—RUBBER-FERRULE MOLDS THAT MAKE MANUFACTURE EXPENSIVE

Radii at the Ends of the Ferrules Necessitate a Complicated Mold with Radii Cut in the Top and Bottom Plates, as Shown in the Mold at the Left. The Mold at the Right Has Engraved Cavities That Are Very Expensive To Make

In making boots for hydraulic-brake systems, it is very easy to design around some of these troubles. At the left in Fig. 9, the top drawing shows a bellows-type boot which would be very hard to strip from the mold pin because of the steepness of the convolutions. Below is a drawing of one that would be much easier to make and which would actually work better in the braking system.

Good illustrations of the desirable thing to do on bumpers and similar molded parts are shown in the two middle sketches in Fig. 9. The mere addition of a radius to the lower portion of the bumper (upper sketch) makes it necessary to machine a cavity in a top plate, whereas, if this radius can be eliminated, a perfectly

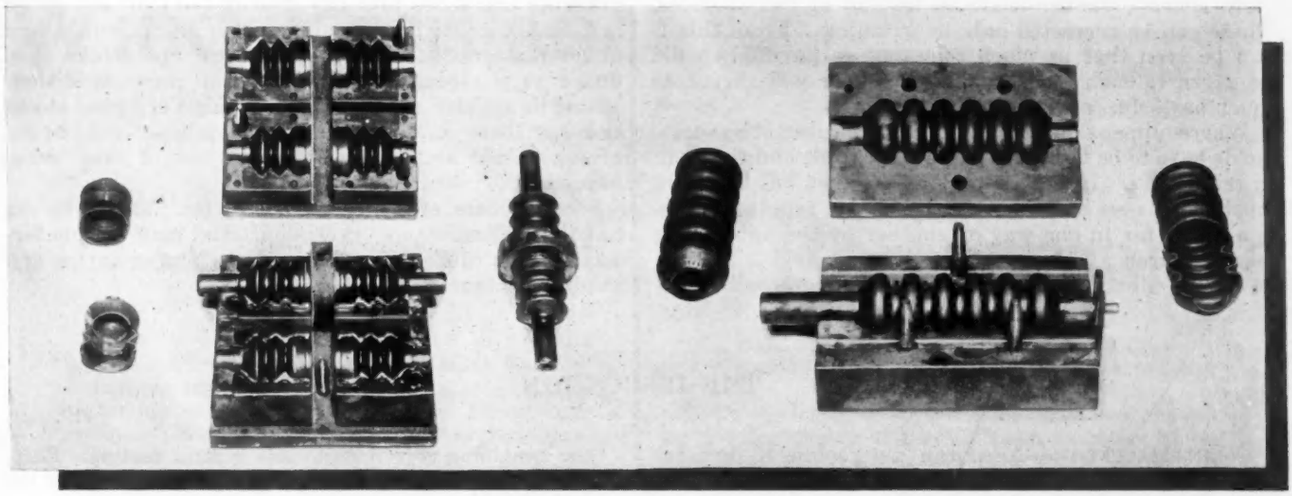


FIG. 8—SIMPLE MOLDS AND CORES FOR BOOTS AND DUST COVERS

Operators Must Assemble and Take Apart the Molds Many Times per Day. If the Design of the Rubber Part Is Complicated, the Molds Often Must Be Made in Four or Five Pieces, Hence the Exercise of Care in Design Is Important

flat plate may be used to cover the mold, as below.

Another part, which may be designed in two ways without materially affecting its functioning, is shown in the drawing at the right. The upper design makes it necessary that the mold be made in four parts, with the possibility of trouble in extracting the rubber part from the mold, while the lower design makes the mold a very simple one, with very little trouble in extracting the piece.

These are merely examples showing specific cases in which considerable time has been saved by small changes in design that do not in any way affect the functioning of the parts. This does not mean that it will be as simple to make all parts as free from trouble as these. It merely shows that we should watch all of our designs for these characteristics.

Effect of Dimensional Variations

As has been mentioned before, exact dimensions are very hard to obtain in most rubber parts. Each stock varies greatly in shrinkage, as do different shapes. Inserts of different materials also cause distortions in shrinkage. Pure-gum stocks shrink much more than do reclaimed stocks. High-temperature cures cause more shrinkage than do low-temperature cures.

A burlap-backed mat of high reclaimed-stock content will remain flat after curing; those of high gum-content will warp and twist. Parts having rubber cured between metal will

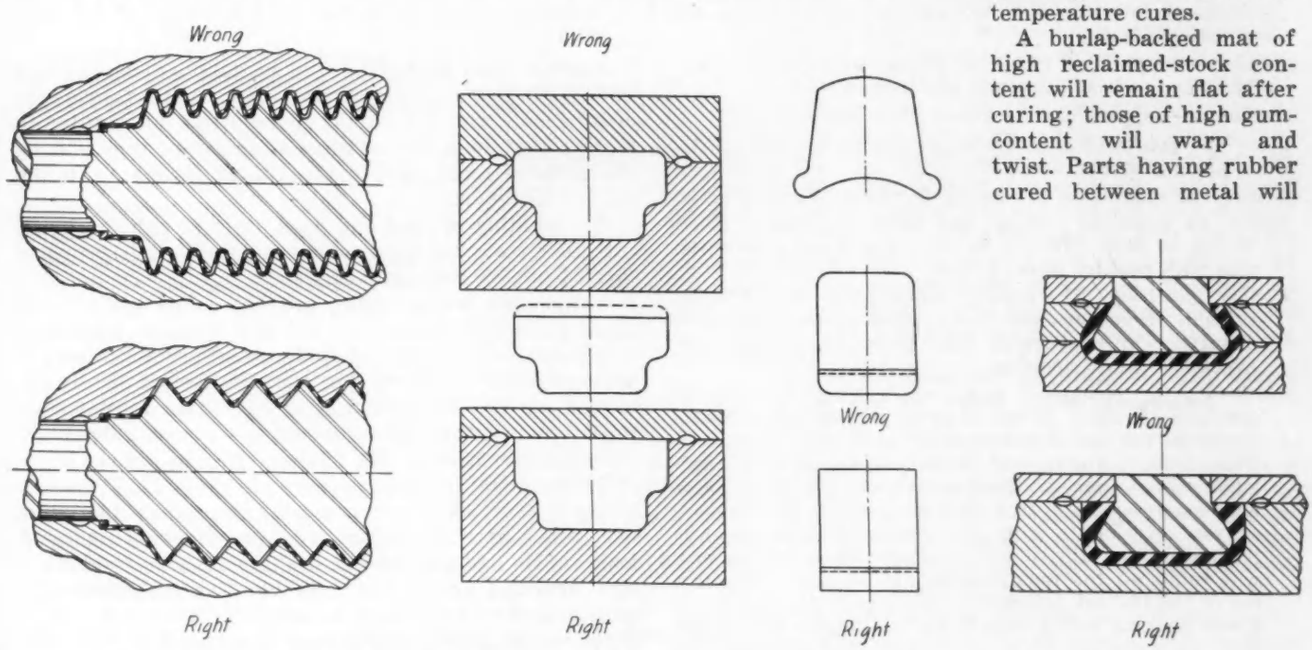


FIG. 9—EXAMPLES OF WRONG AND RIGHT WAYS OF DESIGNING RUBBER BOOTS, BUMPERS AND SIMILAR MOLDED PARTS

Steep Convolutions Make the Part Difficult To Strip from the Mold, Which Is Hot and Loses Heat Every Minute It Is Out of the Press. The Addition of a Radius to the Lower Portion of a Bumper Makes Necessary the Machining of a Cavity in the Top Plate of the Mold, Whereas if the Radius Is Omitted a Flat Plate Can Be Used. In the Piece at the Right, if the Sides Are Made Perpendicular Instead of Sloping Inwardly, the Mold Can Be Made in Three Instead of Four Parts

have concave rubber surfaces instead of flat surfaces. These can be corrected only by grinding. From this it can be seen that as much tolerance as possible should be given to such parts. A good rubber will shrink as much as ⅛ in. to the foot.

Where dimensions must be held to close tolerances, molds have to be figured as close as possible and then run in trial cures. If the dimensions are then off, the mold must be cut over and the whole procedure repeated. This is all paid for in one way or another by the automobile manufacturer, and in some cases is necessary.

We are all familiar with the checked and brittle appearance of rubber that has aged in the sunlight. This is most noticeable in overcured rubber stocks, stocks held under tension, those kept under heat, and stocks aged under very strong sunlight. All of these conditions should be avoided as much as possible. Very good stocks to resist these conditions are now available, and the engineer should not hesitate to make use of them when necessary.

Some rubbers, on aging, become softer. This is known to rubber chemists as "reversion," and may be counteracted by the rubber manufacturers by proper curing and sulphur content.

THE DISCUSSION

COLIN MACBETH[2]:—American automobile design reveals a substantial increase in the use of rubber at points of attachment between sprung and unsprung parts; but in this respect the European use of Silent-Bloc shackles, even by very conservative producers, goes to make the European car a "grease-gunless" job.

There appears to be little that properly proportioned rubber-mixing cannot do today so far as oscillating bearings are concerned. I would recommend their thorough trial on universal-joints of Hotchkiss drives; also as applied to overhead-valve rockers. The latter application would have to take care of overheating, and no oil should come near the valve-rockers. Successful application at such points would go far to reduce noise and would obviate many of the reasons calling for expensive work as regards oil-tight covers.

Increased usage of rubber is desirable at the following points:

Steering Connections—as bushings and joint covers

Springs—as interleaves, to obviate the use of grease and gaiters or boots

Fenders—as packing from the frame, at bracket connections and as head-lamp and side-lamp washers

Radiators—as packings for frame bolts and hoods

Dash—at points of attachment to the frame and of the steering-gear and accessories

Bodies—as substantial insulators to allow frame distortion

Doors—as combined hinges and draft excluders. There should be little difficulty in providing these in conjunction with positive metal hinges.

Rubber Panelling—The modern fabric finish should be obtainable in rubber-sheet form, allowing of considerable distortion in emergency, thus obviating damage now arising to fabric covering.

Seats—Having conducted many experiments toward the adoption of rubber in lieu of metal seat-springs, I would commend the use of rubber-diaphragm type of seating. This, as so far developed, is best arranged as a laced-rubber diaphragm stretched on a metal or wooden frame and supplemented with a hair-and-leather or hair-and-canvas covering to give the conventional appearance. Such seats are still subject to improvement before they will fulfill all the requirements of the user. Effective use of the Hairlok principle of latex-dipped horsehair as a seat packing will, I believe, go far toward overcoming the remaining objections to this type of seating. Hairlok is being developed in the United States by one of the largest rubber manufacturers.

Rubber Floorings—The increasing adoption of sunk wells for the rear floors of automobiles calls for a one-piece floor covering. For this I advocate the use of sponge-rubber-backed moquette, such as will give a jointless and sound-reducing flooring combined with a substantial vibration damper below the feet. It is obvious that the increasing demand for sunk floors will lead to the more general use of worm drives, which will provide an unbroken sunk floor right across the car.

Rubber Doors—The almost universal use of closed cars and the need for flexible non-squeak doors bring one back to the thought that a molded-rubber door is an economic possibility. This could be made so as to allow of molding-in or screw-attaching the metal parts. For instance, the hinges would be best arranged to attach by screws to allow of replacement in case of accidental damage. The locks could well be molded into place. Fabric or paint finishes could be allowed for equally well. Fabric coverings would reduce the cost and weight of the doors to a minimum.

Another item that could well be supplied as a rubber unit is the tops of covered cars. Here again fabric covering inside and out would be required. I venture to predict that in a few seasons sliding-roof tops will be standard on most cars in the United States as in the United Kingdom.

The molding of roof and door parts of rubber should cut labor costs on big-production jobs if it is properly carried out on well-planned lines.

Automobile bodies today are not called upon to do much more than keep out wind and weather, and their construction from light, flexible sound-proof rubberized units, suitably adapted for the attachment of lights, hinges and the like should be of advantage to manufacturer and user in these days of low-priced rubber.

BURGESS DARROW[3]:—Mr. Lee said that he did not know anything about rubber four years ago. He certainly knows a great deal now, and we rubber manufacturers owe him a vote of thanks for his comments on mold design. He has pointed out the importance of mold design time and again, and I would like to say that this applies to tires as well as to other molded goods. This is the second time I have heard Mr. Lee talk, and both times it has served as an inspiration to me, because he has pointed out how many parts of the automobile can be made of rubber.

[2] F.M.S.A.E.—Consulting mechanical engineer, rubber expert, Birmingham, England.

[3] M.S.A.E.—Manager, development department, Goodyear Tire & Rubber Co., Akron, Ohio.

Wind Resistance versus Car Performance

Indiana Section Paper

By Louis Schwitzer[1]

INCREASE in automobile speed, made possible by highway improvement, and the probability that still higher speeds will be possible in the future make it necessary that high speed be arrived at more economically and with greater safety.

Wind resistance is the greatest factor limiting high speed and fuel economy. Many advantages could be gained if engineering effort were directed toward streamlining cars and reducing their frontal area. Although a car designed to greatly reduce the wind resistance would deviate widely from customary design, the author believes that when its performance and economy are demonstrated the sales resistance can be overcome. He predicts that rear-engine-driven streamlined cars will make their appearance in America within a few years.

Facts developed in European investigations regarding the disturbance of the airstream by bodies of various shapes are given and data are presented on power losses and power utilization in a car designed by Rumpler in Germany and in two German racing cars incorporating the Rumpler principles. Comparison of these data with those of conventional cars shows a large reduction in power absorption by wind resistance, with consequent reserve power available for hill climbing or higher speed. Novel design features of the streamlined cars are illustrated and briefly described.

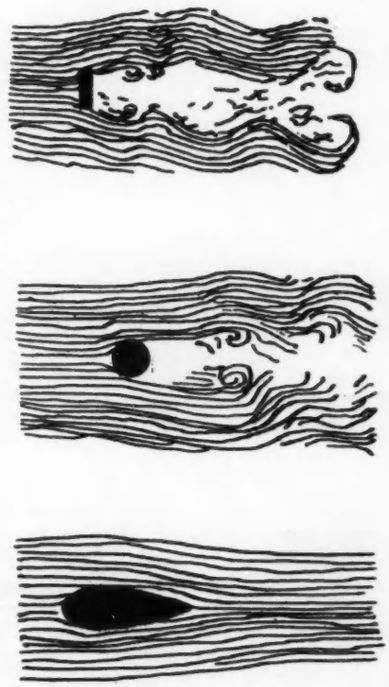


FIG. 1—AIR-FLOW AROUND BODIES OF VARIOUS SHAPES

A Flat Body with Its Plane Vertical to the Air-Flow Produces a Disturbed Airstream and a Partial Vacuum and Eddy Currents at the Rear, as in the Top Drawing. Similar but Less Intense Effects Are Produced by a Cylindrical Body, as in the Middle Drawing. A Rain-Drop-Shaped Body Causes the Minimum Air Resistance, the Round Leading End Parting the Airstream Smoothly, as in the Lower Drawing, and No Vacuum or Eddies Are Produced at the Rear

WITH the development of better roads, the average speed of the motor-car has increased during the last three or four years by at least 15 m.p.h. Performance requirements have gone up proportionately, and few automobiles are built today that cannot attain a speed of 65 or 70 m.p.h. If the motor-car shall retain its undisputed position as the premier means of individual transportation, still higher road-speeds must be possible in the future.

All of us are aware of the great additional increase in power output that is necessary to give a few additional top-speed miles per hour and a few of us realize the cost of these few miles in the initial price of the car and in operating expense. Therefore it will be necessary that these high road-speeds be arrived at more economically than heretofore and with greater safety. The road systems will have to be improved by widening and the establishing of one-way roads, eliminating grade crossings, the adoption of automatic traffic regulation and probably by lighting the highways at night, but the real solution lies in the designing of the motor-car itself.

Wind resistance is the greatest factor that has limited car performance and economy. Automobile designers have been very slow, particularly in this Country, to realize the gain that can be made by taking a lesson from airplane design and devoting to useful work the great amount of energy that is wasted in overcoming the wind resistance of present motor-cars. If the laymen who purchase and drive the cars we build knew just what our hard-beaten engines and the present body designs do to the gasoline that they pour into the tanks, and how much a change of design could affect the conditions, it is probable that our present-day cars would be carrying streamlined bodies.

Streamline Advantages Will Overcome Sales Resistance

All of us who use the Indianapolis Speedway for our high-speed test work have learned that, in our cars of conventional design, top speed is virtually unaffected by vehicle weight, the important factors in high speed being primarily frontal area and streamlining. If the right engineering effort were directed toward these items, many advantages could be gained and a great part of the present disturbing deficiencies eliminated. Some of the possibilities of a new design are:

Smaller and lighter powerplants that would give

[1] M.S.A.E.—President, chief engineer, Schwitzer-Cummins Co., Indianapolis.

equal car performance with a much lower fuel and oil consumption; shorter wheelbases with equal body comfort, the result being a decided reduction in total car weight and elimination of the heavy-car brake problem; better riding-qualities; higher top-speeds with greater safety; and, what is most needed, superior acceleration because of weight reduction. Smaller powerplants can be built in more perfect balance with fewer diffiulties than can large engines and therefore are smoother running, and the bearing, lubrication and carburetion problems become less complex.

A car designed to cope with the wind-resistance problem probably will deviate from the present conventional design; however, today it is barely possible to distinguish one manufacturer's product from another's and it is again time to strive for individuality. I believe that automobile drivers are certainly better informed than they were a few years ago and will appreciate the advantages of a streamlined vehicle as soon as such a vehicle is demonstrated to them.

With the present intensive competition among automobile manufacturers, it is certain that within the next few seasons some manufacturer will build a car that is capable of an impressive demonstration. When that time arrives, ideas as to what constitutes a beautiful car will change as rapidly as do ideas of what consti-

TABLE 1—COMPARISON OF POWER LOSSES AND RESERVE POWER AVAILABLE IN A CONVENTIONAL CAR AND THE RUMPLER STREAMLINED CAR AT TWO ROAD-SPEEDS

	Speed			
	50 M.P.H.		60 M.P.H.	
Power	Conventional Car	Rumpler Car	Conventional Car	Rumpler Car
Available at Flywheel, per cent	100.0	100.0	100.0	100.0
Losses				
In Power Transmission, per cent	13.7	8.5	13.7	8.5
By Road Friction of Rear Tires, per cent	18.3	9.0	18.3	9.0
By Road Friction of Front Tires, per cent	4.6	3.0	4.6	3.0
By Air Resistance or Blower Action of Spokes, per cent	2.3	1.5	2.3	1.5
By Air Resistance of Car, per cent	33.0	13.5	61.1	24.5
Available Reserve for Acceleration and Hill Climbing, per cent	28.1	64.5	0.0	53.5

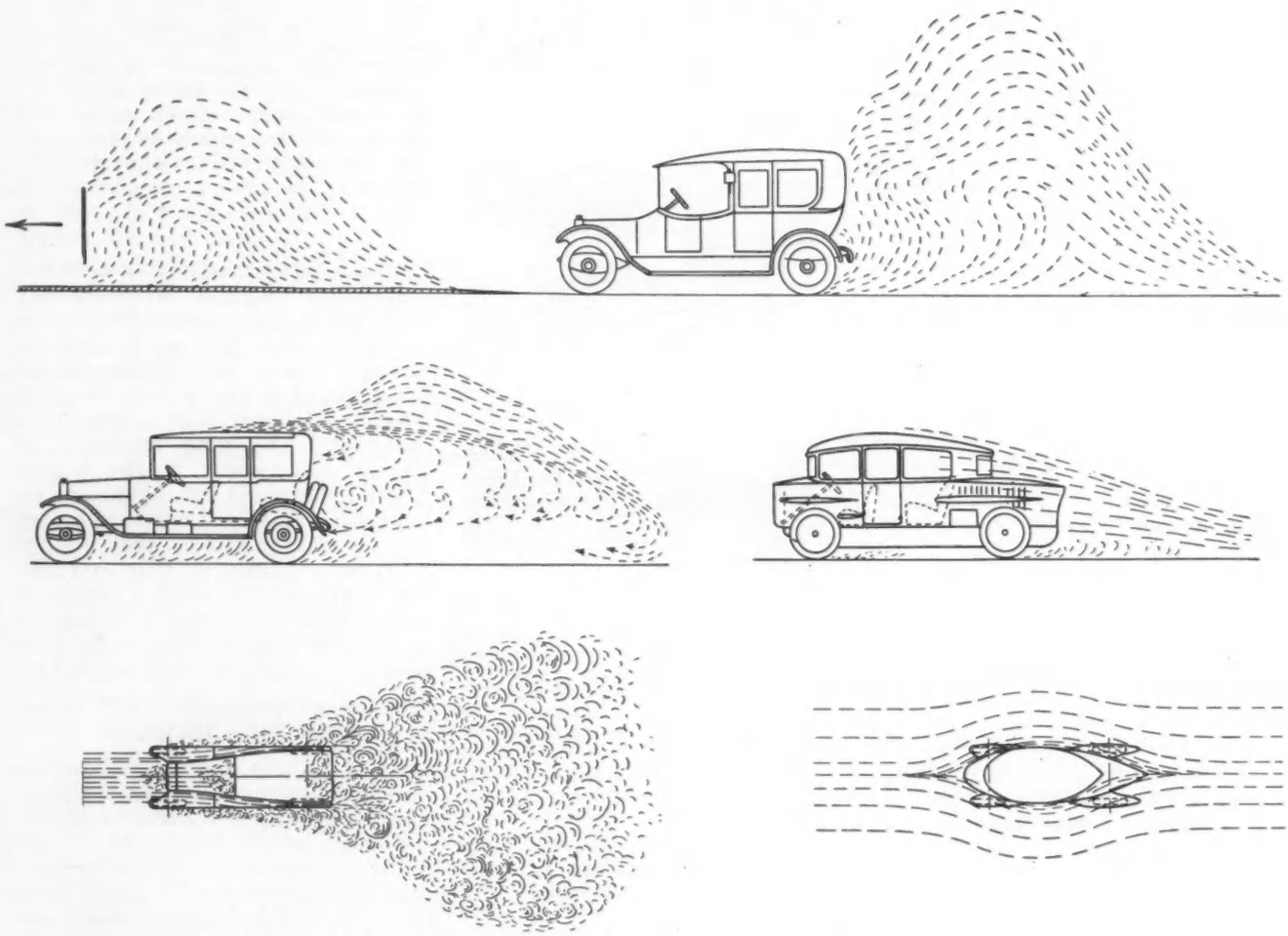


FIG. 2—COMPARISON OF AIR DISTURBANCE CAUSED BY CONVENTIONAL AND STREAMLINED AUTOMOBILE BODIES

The Conventional Closed Body Produces Much the Same Air Disturbance as the Flat Plate, as Shown at the Top. Whereas the Usual Car Forces the Air above the Top and Creates Back-Drafts and Eddies, the Rumpler Streamlined Car, Shown in the Middle Sketch, Causes It To Flow Smoothly Over and Behind. The Dust Cloud and Airstreams Produced by the Conventional and Rumpler Cars Are Shown in the Top-View Sketches at the Bottom

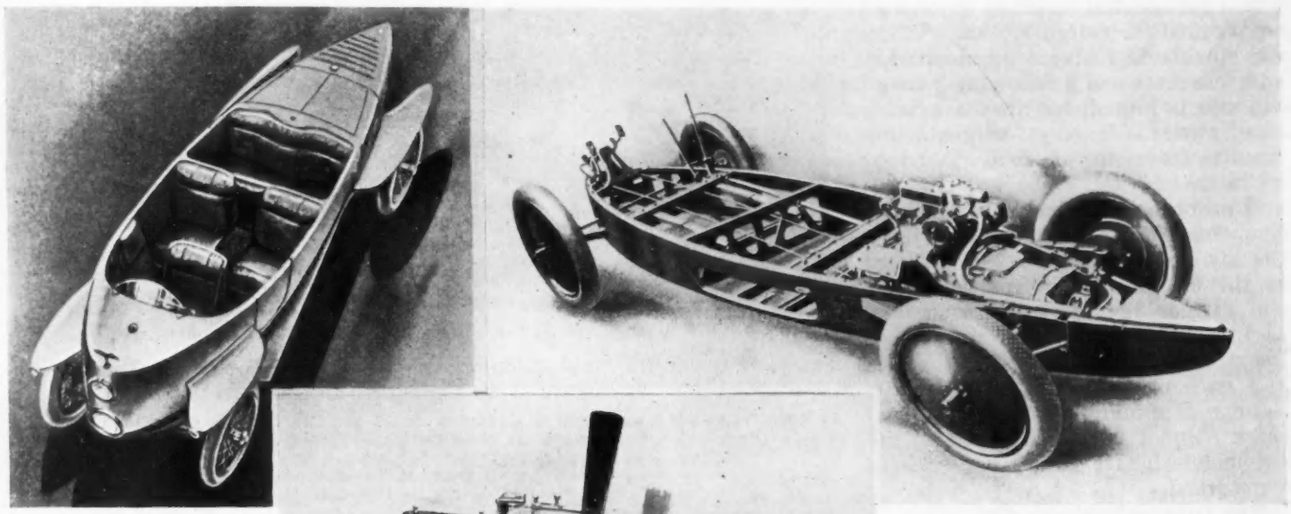


FIG. 3—RUMPLER STREAMLINED CAR, CHASSIS AND ENGINE

The Novel Seating Arrangement Places All Passengers between the Axles, Which Is the Most Comfortable Riding Place. The Engine Is in the Rear and Directly Connected to the Transmission and Rear-Axle Drive. It Has Six Cylinders Arranged in Double-V Form. The Chassis Has a Very Deep and Rigid Frame and Independently Sprung Wheels

tutes any style. Sales resistance to a streamlined car could, I believe, be cancelled out at the very beginning by the attraction of increased performance and economy. Furthermore, if we can make our present designs so obsolete that nobody will want them, what a stimulus this will give the industry. I believe that streamlined rear-engined cars with independently sprung wheels will appear within a few years. The advantages of such a design are manifold. It makes possible simpler construction, higher mechanical efficiency, better riding-qualities, avoidance of heat in the driving compartment and better accessibility, and places all engine noise behind the passengers.

Early Scientific Research in Germany

A thorough scientific research was made as early as 20 years ago by Professor Riedler at the University of Charlottenburg in Germany on the absorption of the energy in motor-cars, and I shall show with diagrams what a large factor wind resistance is in the absorption of the available energy. But first let us consider some of the fundamentals which were established by research work at the Eiffel laboratories in Paris.

If a flat body moves through the air in a direction vertical to its plane, as in the upper drawing in Fig. 1, or if the air moves toward it, disturbed airstreams and eddy currents are produced. The air is violently parted by the flat surface, and be-

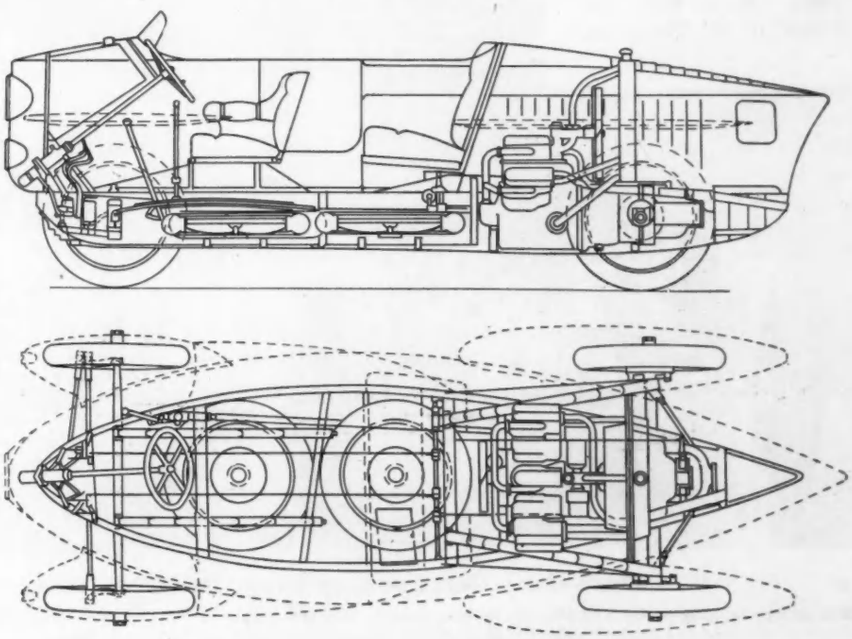


FIG. 4—VERTICAL AND PLAN DRAWINGS OF THE RUMPLER CAR

Note Arrangement of Steering-Gear and Location of Spare Tires, Radiator and Fan. The Exhaust Pipe Expels the Gases through the Tail of the Chassis Where They Are Carried Away in the Airstream

hind it a partial vacuum is created which tends to retard motion. If the flat surface is replaced by a cylinder, eddy currents and a following vacuum are still produced, but they are much less intense. A very similar action results from the use of V-shaped radiators.

However, if a body having the shape of a rain drop is moved through the air, the air resistance is reduced to the minimum; the round leading end divides the airstream smoothly, as in the lower drawing, permitting the stream to converge without eddies and without a vacuum at the rear. Because of design difficulties this ideal shape cannot be duplicated in the automobile but it can be very closely approached.

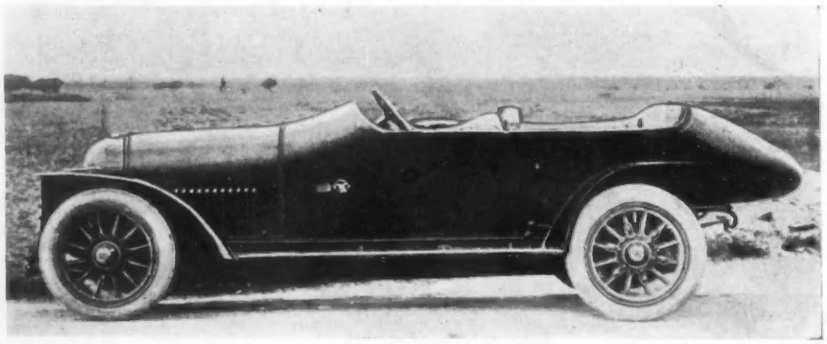
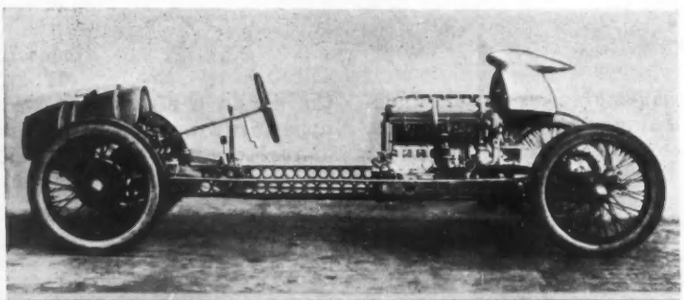


FIG. 6—THE 100-HP. BENZ RACING CAR WITH WHICH POWER-ABSORPTION EXPERIMENTS WERE CONDUCTED IN GERMANY

It Weighed 3400 Lb. and Had a Maximum Speed of 83.75 M.P.H. The Engine Had a Piston Displacement of 380 Cu. In. and Developed 104 B.Hp. with Muffler Attached. The Power Available and Its Disposition Are Plotted in Fig. 7

The conventional car has about the same action in the air as a flat plate, as illustrated at the top in Fig. 2. Mr. Rumpler, one of the foremost aviation engineers in Europe, designed a motor-car of streamlined type about 16 years ago. It was lacking in attractiveness of appearance but showed remarkable ability compared with the usual design and had mechanical features that should be given serious consideration, as I believe that they form a nucleus of a new, logical and advanced design.

The middle sketches in Fig. 2 tell their own story as regards wind resistance. The air is forced above and behind the conventional car into eddies and back-drafts, whereas it streams smoothly over and behind the Rumpler. To demonstrate this visually, cars of both types were driven over a dust-covered road and the formation of dust clouds observed. They were exactly as depicted in this drawing and as shown in the plan views below. The only dust raised in actual tests with the Rumpler car was small clouds from the rear wheels. Any two vehicles can be quickly compared as to their wind-resistance characteristics by driving them at equal speeds over a stretch of dusty road, the car raising the more dust having the higher resistance.



Comparison of Rumpler and Conventional Car

Comparative data from actual tests of the conventional car and the Rumpler relative to the available horsepower at certain speeds and the power losses through friction and resistance are given in Table 1. Both cars had a piston displacement of 169 cu. in. and both were tested on the same drum dynamometer and road. Note in particular that the losses by road friction of independently sprung wheels are only one-half those of conventionally sprung wheels.

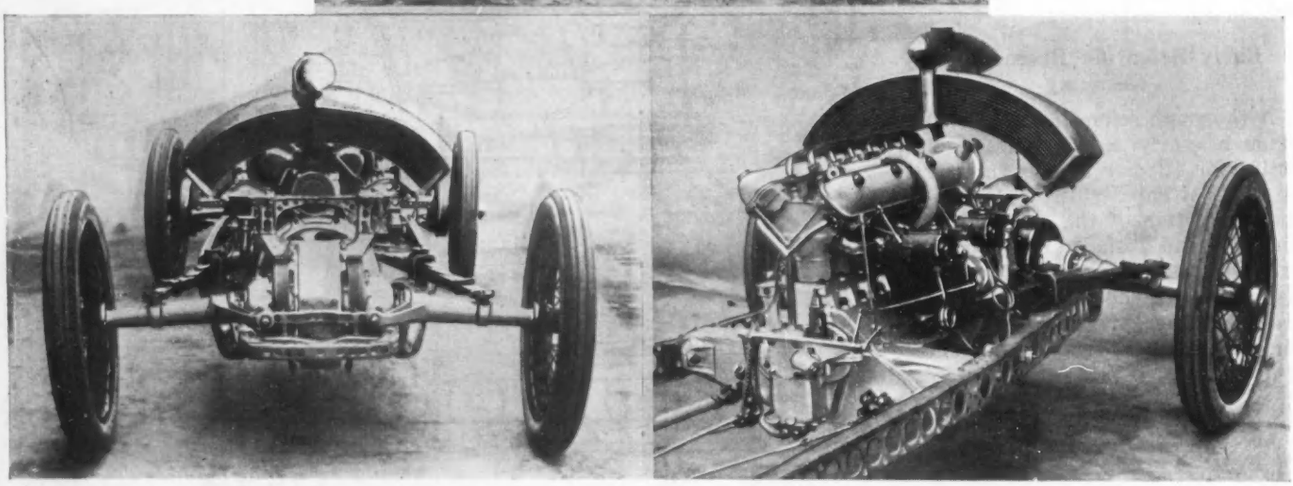


FIG. 5—SMALL MERCEDES-BENZ RACING CAR BUILT ON THE RUMPLER PRINCIPLE

Driven by an Engine of 122-Cu. In. Displacement, without Supercharger. This Car Attained a Speed of 127 M.P.H. The Feasibility of the Rear-Engine Design, Which Has Numerous and Obvious Possibilities, Is Shown in the Lower Views

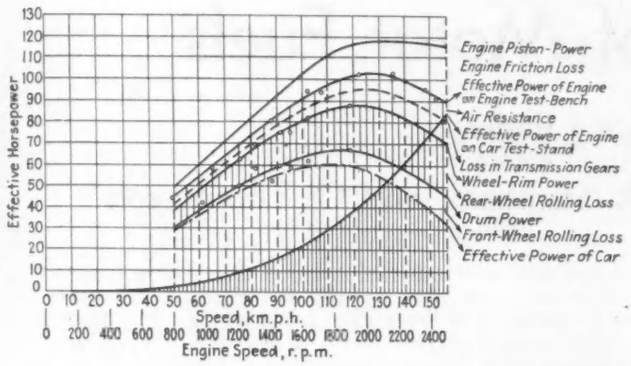


FIG. 7—POWER LOSSES AND UTILIZATION IN THE 100-HP. BENZ RACING CAR

Space Between the Top Two Curves Shows the Power Lost in Friction in the Engine. Other Losses Are Represented by Spaces Between the Various Power Curves. Increase of Air Resistance with Speed Is Indicated by the Bottom Curve. The Maximum Car-Speed Is 134 Km.P.H. (83.75 M.P.H.), Where the Curve of Air Resistance Crosses the Curve of Effective Power of the Car

Views of the Rumpler car in Fig. 3 show the general appearance with and without body. Note the seating arrangement; all passengers ride between the axles, which is the logical place for comfortable riding. Doors can be ideally arranged and are not half cut away. Both the front and rear doors afford sufficient room for easy entrance and exit, without the usual necessity for squeezing through the doors. Note in the chassis view the independently sprung wheels, the depth of frame, the rigidity and the arrangement of cross-bars. An interesting arrangement that is possible with rear-engine-driven cars is that the front springs are inside the frame, which permits a shorter turning radius.

The powerplant is a six-cylinder assembly built in three banks of two cylinders each arranged in double-V form and directly connected to the transmission and the rear-axle drive, as seen in the lower view of Fig. 3. Notable features of the assembly are the location of the emergency brake and the rear suspension of the entire powerplant.

The arrangements of steering-gear and spare tires and the location of the radiator and fan, as shown in the vertical and plan drawings in Fig. 4, are also of interest. Another interesting feature is the location of the exhaust pipe in the tail of the frame, where the exhaust gases should be carried away by the airstream.

Power Utilization in Benz Racing Cars

A racing-car chassis built by Mercedes-Benz on the Rumpler principle, with rear-engine drive, is shown in Fig. 5. An idea of the possibilities of a car of this design is given by the fact that, with a 2-liter-displacement (122 cu. in.) engine, without supercharger, this particular Mercedes-Benz automobile attained a speed of 127 m.p.h. The lower views further indicate the feasibility of rear-engine design, the possibilities of which are both numerous and obvious.

The 100-hp. Benz racing car with which the Charlottenburg experiments were conducted is shown in Fig. 6. This car competed in the Prince Henry competition and carried three passengers as prescribed by the regulations. The car weighed 3400 lb., and the 4½ x 6-in. four-cylinder engine had a displacement of 380 cu. in. Some of the principal characteristics of the car are as follows:

Maximum Speed, m.p.h.	83.75
Engine Indicated Horsepower	118
Engine Brake Horsepower, with muffler	104

The power available for driving this car, and its disposition, are represented graphically in Fig. 7. The top curve, representing the piston power, or indicated horsepower, peaks at 118 hp. and 2050 r.p.m. The sec-

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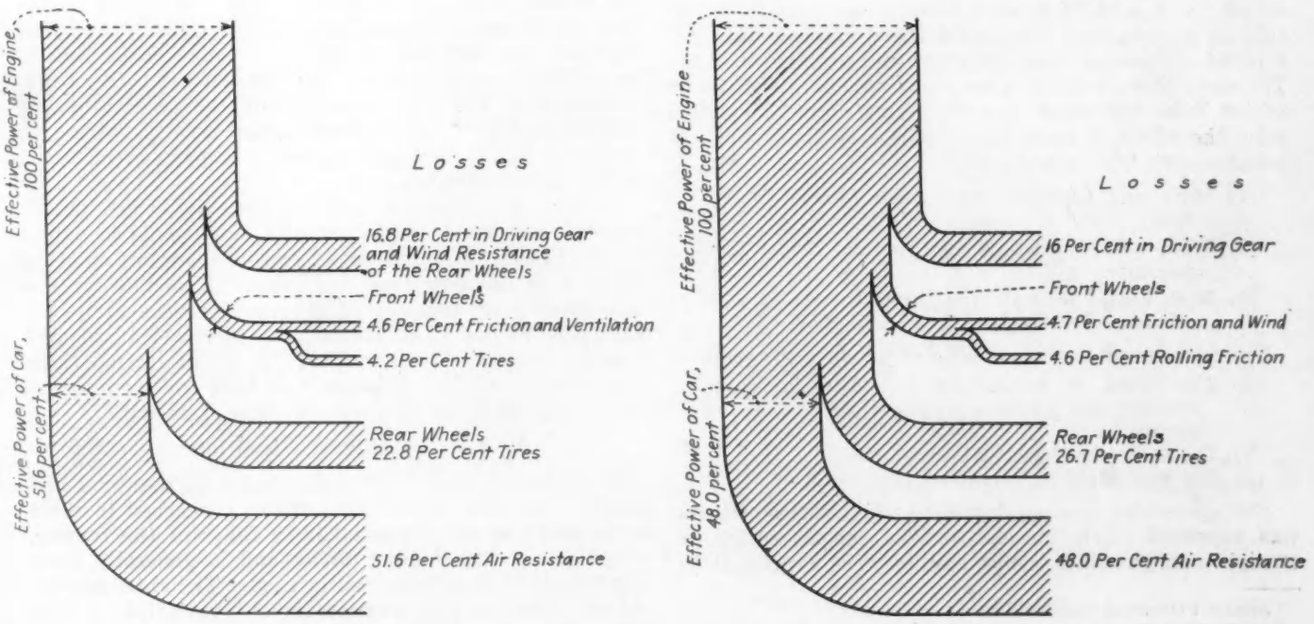
Effective Power of Engine, 100 per cent
Losses
16.8 Per Cent in Driving Gear and Wind Resistance of the Rear Wheels
Front Wheels
4.6 Per Cent Friction and Ventilation
4.2 Per Cent Tires
Effective Power of Car, 51.6 per cent
Rear Wheels 22.8 Per Cent Tires
51.6 Per Cent Air Resistance
Effective Power of Engine, 100 per cent
Losses
16 Per Cent in Driving Gear
Front Wheels
4.7 Per Cent Friction and Wind
4.6 Per Cent Rolling Friction
Effective Power of Car, 48.0 per cent
Rear Wheels 26.7 Per Cent Tires
48.0 Per Cent Air Resistance

FIG. 8—ENERGY DIAGRAMS OF 100-HP. BENZ RACING CAR AND 75-HP. ADLER TOURING CAR

Absorption of Effective Engine Power at 2120 R.P.M. in the Benz at a Car Speed of 83.75 M.P.H. Is Shown in Percentages at the Left. That for the Adler at an Engine Speed of 2290 R.P.M. and a Car Speed of 70.83 M.P.H. Is Shown at the Right

Knock Rating of Motor Fuels

Annual Meeting Paper

By C. H. Barton,[1] C. H. Sprake,[2] R. Stansfield[3] and O. Thornycroft[4]

EXPERIMENTS carried out in 1930 by the Knock Rating of Motor Fuels Subcommittee of the Institution of Petroleum Technologists are described in the paper which, in reality, is a continuation of one presented at the 1930 Annual Meeting of the Society. Various fuels, both straight run and blended, were tested in the Ricardo 2-liter E-35, the Delco and the Armstrong engines under three different sets of conditions and were rated in terms of blends of a high-value and a low-value straight-run gasoline, benzene and heptane and iso-octane and heptane. The last method gave a greater degree of fluctuation in knock intensity than the benzene-heptane blend, and in the future all knock ratings will be expressed in terms of the octane number, which is in agreement with knock-rating practice in the United States.

A SHORT paper was read at the 1930 Annual Meeting of the Society dealing with tests carried out by the research laboratories of the Anglo-American Oil Co., the Anglo-Persian Oil Co. and the Asiatic Petroleum Co. to determine the agreement that could be obtained on three widely different designs of test engine when the gasolines in common use on the British market were examined. We realized that this range was comparatively narrow and that further work would probably be necessary. The results obtained encouraged the belief that reasonable agreement might be reached with a greater range of fuels.

British Tests Reviewed

An extended program was therefore planned and put into effect, and the results of the second series of tests were communicated to the Detonation Subcommittee of the Cooperative Fuel-Research Committee through Dr. H. C. Dickinson. These tests included the rating of five straight-run gasolines varying from a very high anti-knock value, a blend of high benzol-content, blends containing vapor-phase and liquid-phase cracked gasoline, a blend containing lead tetraethyl and an alcohol blend. The same three engines were used; namely, the Ricardo 2-liter E-35, the Delco and the Armstrong. To determine the effect of running technique as thoroughly as possible each fuel was tested

(1) With cold inlet-air and normal jacket-temperature
(2) With heated inlet-air and normal jacket-temperature
(3) With heated inlet-air and the jacket cooled with ethylene glycol at about 375 deg. fahr.

The fuel samples were rated in three ways in terms of

(1) The blend of a high-value and a low-value straight-run gasoline required to match the sample
(2) The equivalent benzene-heptane blend
(3) The equivalent iso-octane-heptane blend

The agreement reached during the first series of tests was repeated fairly closely for the second series of straight-run gasolines, when results were expressed in terms of the high and low-value straight-run gasoline substandards; but the results differed more when the fuels were rated in terms of the pure hydrocarbons, and pronounced disagreement was noted in the cases of the fuels that were not straight run. No particular variation appeared to be caused by the use of the throttling method as compared with the variable-compression method, but the agreement was definitely improved when the inlet air was heated to about 120 deg. fahr. before entering the carbureter. This appears to be preferable to the application of unlimited heat in the manifold. The bouncing pin was the most satisfactory means for measuring knock intensity if the engine was small enough for it to function properly.

Ocane-Number Standard Is Best

The results obtained tended to show that iso-octane, at least in the two engines that used this standard, gave a greater degree of fluctuation in knock intensity, than did benzene, but this is obviously a point that can be decided only in reference to the particular engine and technique ultimately adopted. We understand that tests on the Horning engine have shown iso-octane to be rather more consistent than benzene and, therefore, members of the Subcommittee of the Institution of Petroleum Technologists have agreed that, in future, all knock ratings of gasolines shall be expressed in terms of the octane number.

Reverting to the test results from the three British engines, we saw at once that little hope could be found of correlating the majority of testing plants of existing types with the new standard engine, although correlation should be possible if determined separately for each type of fuel used. Some such correlation probably will be necessary to bridge over the period during which laboratories in all parts of the world are making changes from their existing plants to the new standard.

Coil or Magneto Ignition

Experiments have been conducted with both coil and magneto ignition in the laboratories concerned in these tests, and the opinion in all is in favor of the former, which has given steadier firing and is generally more dependable if a suitable coil is used. The chief technical objection to the magneto is the variation in flux density on account of both aging and timing adjustment. The problem of battery charging was thought to be of

(*Concluded on p.* 641)

[1] Asiatic Petroleum Co., London.
[2] Anglo-American Oil Co., London.
[3] Anglo-Persian Oil Co., London.
[4] Deputy director of research of the British Air Ministry, London.

The Cooperative Fuel-Research Committee Engine

By H. L. Horning[1]

Annual Meeting Paper

AFTER stating the three qualifications that should be possessed by a fuel-testing engine as (*a*) universality, (*b*) ruggedness and (*c*) low cost, the way in which all are met is outlined. The construction of the original engine is described in some detail and a table of dimensions of the more important parts given. Refinements that were developed as a result of work with the original engine in the last 2 years affect water-jacketing, condenser-coil location and accessibility of certain parts.

To overcome objections raised as a result of actual experience in fuel testing by members of the Cooperative Fuel-Research Committee, the engine has been recently redesigned to include a variable-compression cylinder, a modified centrifugal type of water pump and magneto-ignition. These changes are described and the reasons for their incorporation in the engine are stated. Illustrations and drawings showing various stages in the development of the engine supplement the text.

AN engine has been developed to meet the requirements of fuel testing as practiced by the leading refineries of this Country. The splendid cooperation by the members of the joint committee of the Society, the American Petroleum Institute and the Bureau of Standards has made this possible. The original recommendations of this group, when summarized, called for an engine design to meet each of the following three qualifications:

(1) The engine should
  (*a*) Be a universal type permitting conversion from an L-head to a variable-compression overhead-valve engine.
  (*b*) Be suitable for throttle, spark, bouncing-pin, listening-post or variable-compression method of testing.
  (*c*) Operate with uniform jacket-temperature.
  (*d*) Have convenient outlets for thermometers, accessory drives and the like.
(2) The engine should be unusually rugged and adapted to withstand continuous operation under heavy detonation.
(3) The design should be simple, to allow a cost that is low enough for the engine to be used generally throughout the industry.

[1] M.S.A.E.—President and general manager, Waukesha Motor Co., Waukesha, Wis.

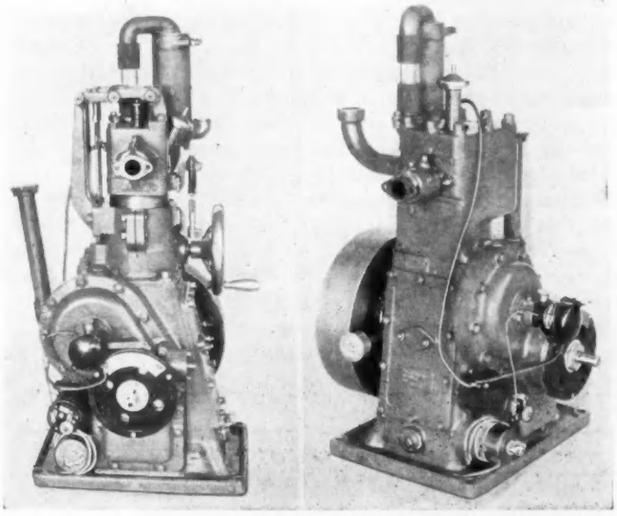

FIG. 1—TWO VIEWS OF THE ORIGINAL COOPERATIVE FUEL-RESEARCH COMMITTEE ENGINE

The Engine Shown at the Left Is Equipped with a Valve-Rocker-Arm Linkage That Automatically Maintains a Uniform Tappet-Clearance as the Cylinder Is Raised or Lowered To Vary the Compression Ratio. The View at the Right Shows the Same Engine Converted to a Fixed-Compression L-Head Unit by Merely Substituting Another Cylinder Assembly

Meeting the Desired Qualifications

Qualification (1) was met by devising a valve-rocker-arm linkage that automatically maintains a uniform tappet-clearance as the cylinder is raised or lowered to vary the compression ratio. This arrangement permits interchangeability between a variable-compression overhead-valve cylinder and a fixed-compression L-head cylinder without disturbing any part of the

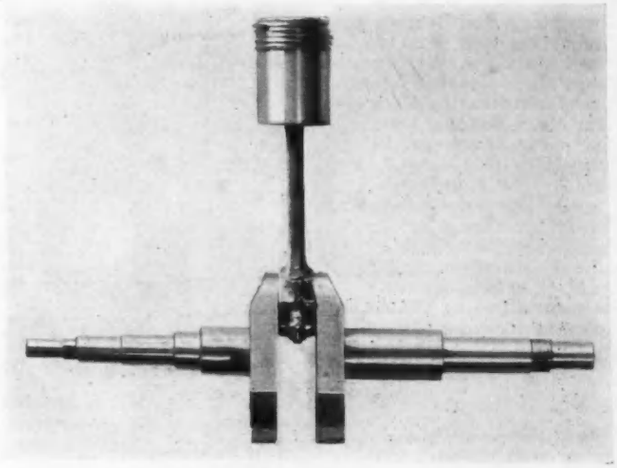

FIG. 2—CRANKSHAFT OF THE ENGINE

Features of This Crankshaft Are Its Weight and the Large Bearings Used. The Dimensions of the Latter Are Ample for a Heavy-Duty Engine 60 Per Cent Larger and Operating at Three Times the Speed

crankcase or camshaft drive. The view at the left in Fig. 1 shows this linkage and other special features, such as the micrometer screw for measuring cylinder height, the steam-cooling condenser, the tachometer-drive outlet, the oil-heater control-switch and the neon-tube spark-position indicator mounted on the front end of the crankshaft. The other view shows the same engine converted to a fixed-compression L-head unit by merely shifting cylinder assemblies.

Qualification (2), regarding ruggedness, was simply a question of fundamental engine-design. Fig. 2 shows the heavy, counterweighted, large-bearing crankshaft. The bearing dimensions are ample for a heavy-duty engine of 60 per cent larger dimensions, operating at three times the speed. The rear bearing is made doubly long by spaced bushings to resist flywheel wabble. The cast-iron piston is of heavy section with a long, smooth skirt. It carries four compression rings and one oil-control ring. These features permit an accurate fit in the cylinder with the minimum of ring tilting. The heavy metal-section provides good heat-conduction and makes a rigid structure that prolongs the life of the parts. The piston-ring seal is, of course, vital in maintaining uniformity of pressure conditions during combustion, and the piston has been designed to furnish the best ring-operating conditions without compromise of any sort. The connecting-rod is long to reduce angularity and has a wide section to provide rigidity.

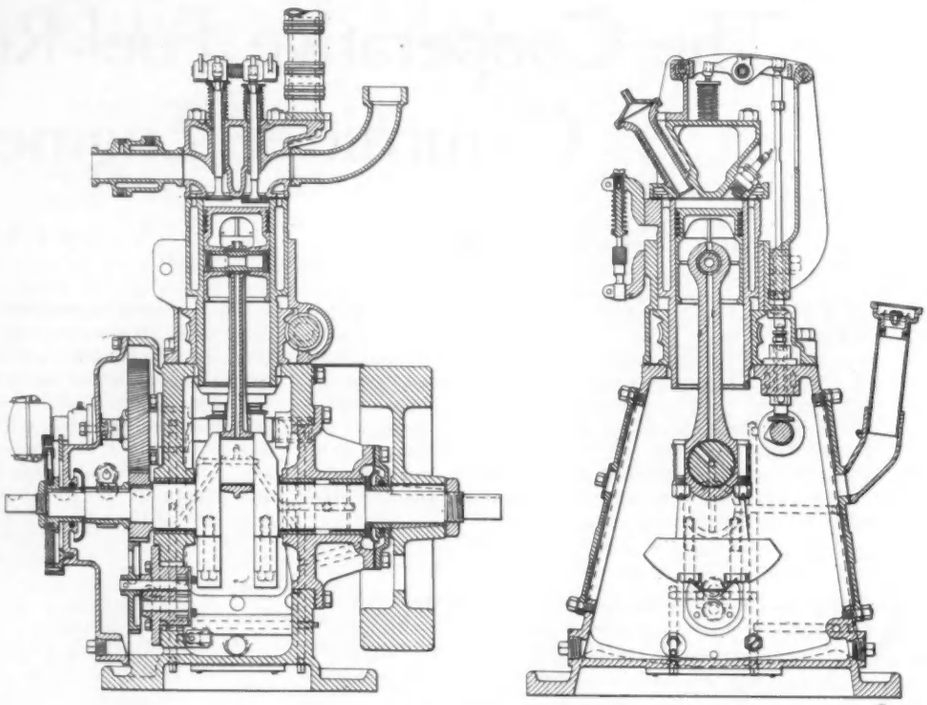

FIG. 3—LONGITUDINAL AND TRANSVERSE SECTIONS OF THE ENGINE

The Crankcase Has Walls 1 In. Thick and Its Height Is Increased by Extending the Cylinder Barrels below the Top Surface, This Increased Height Adding to the Stiffness

TABLE 1—SPECIFICATIONS OF THE COOPERATIVE FUEL-RESEARCH ENGINE

Bore, in.	3¼
Stroke, in.	4½
Cylinder Displacement, cu. in.	37.4
Intake-Valve Diameter, in	1 3/16
Exhaust-Valve Diameter, in.	1 3/32
Connecting-Rod Bearing Diameter, in.	2¼
Connecting-Rod Bearing Length, in.	1⅝
Front Main-Bearing Diameter, in.	2¼
Front Main-Bearing Length, in.	2
Rear Main-Bearing Diameter, in.	2¼
Rear Main-Bearing Length, in.	4¼
Piston-Pin Diameter, in.	1
Connecting-Rod Length, in.	10
Number of Piston-Rings	5
Timing-Gear Face-Width, in.	1
Carbureter Flange	S.A.E.
Carbureter-Flange Diameter, in.	1
Exhaust Manifold Pipe-Tap Size, in.	1¼
Spark-Plug Size, mm.	18
Indicator-Opening Diameter, in.	7/8
Indicator-Opening Threads per Inch	18
Approximate Weight, lb.	450

Fig. 3 shows longitudinal and transverse sections of the engine. The front and rear walls of the crankcase have a metal thickness of 1 in. to provide the necessary rigidity. The box-type crankcase is made extra high by allowing the cylinder barrels to extend below the top surface. This extra height also adds to the stiffness. The main bearings are one-piece cylindrical bushings, the front one being mounted directly in the crankcase wall and the rear pair in a heavy-section carrier that permits removing the crankshaft through the rear end of the case. This type of structure was chosen because of its inherent rigidity. Dimensions of the important parts are given in Table 1.

Meeting qualification (3), that the design be simple and the cost moderate, was made possible by the variable-valve-clearance compensating-linkage previously mentioned and by choosing a cylinder dimension of common size. The bore and stroke of 3¼ and 4½ in. respectively were selected because they corresponded approximately with average passenger-car engines. This permitted convenient production on ordinary equipment. The quantity of fuel required for test with this size of engine was considered moderate, and the detonation characteristics conform more closely to actual passenger-car engines than do those of smaller or larger engines.

Modifications in Original Design

A number of engines have been built in the last 2 years to conform to the requirements as outlined above. These engines have been used in research work by the Committee members and for routine production-control work in plants of some of the Committee members and by others. During this time, refinements have been made in details, such as water jacketing, condenser-coil location, material specifications and accessibility

of certain parts. Recently the Committee has made recommendations for refinements in the engines based on the experience gained in this period. Fortunately, the original design was such that all changes have been conveniently incorporated into the engine without any compromise and all improvements are easily installed on the original engines. The final list of changes includes the variable-compression cylinder, the cooling system, the valve gear and the ignition system.

A water-pump of the modified-centrifugal type having a permanent seal without packing has been attached to the engine as shown in Fig. 4. Nitralloy is used for the pump shaft, and the bearings are porous bronze impregnated with grease. The pump is driven at twice engine speed by a V-belt and circulates 7 gal. of water per min. at 600 r.p.m. of the engine. A lead is taken from the high-pressure point in the pump to circulate water through the manifold jacket. The condenser shown in this illustration has been altered to take in and discharge water at the bottom. The original condenser was arranged to receive steam at the top and deliver condensate at the bottom, the rise to the top of the condenser being utilized to hold back as much of the water as possible in the cylinder jacket and allow only the steam to pass into the condenser. In high-temperature work when using mixtures of ethylene glycol, a forced circulation of the cooling fluid to prevent steam pockets has been found desirable and permits simplifying the condenser construction as shown.

Fig. 4 also shows the magneto-ignition installation that has been worked out as optional equipment. The magneto has the advantage of giving a uniform spark-intensity without requiring the attention that is necessary to keep a battery in charged condition. The magneto-spark intensity over its range of advance is made fairly uniform by using an instrument that is built with trailing pole-shoes for this purpose. The magneto also has the advantage of giving an accurately mounted breakershaft. Bearings on commercial battery-ignition breaker-shafts are not all that could be desired for fuel testing. To obtain an equivalent mounting for the shaft, building a special instrument would be necessary. The magneto is driven directly from the crankshaft through a tubular rubber-duck coupling. This eliminates any tendency to backlash and gives a high armature-speed. One spark is wasted at the end of each exhaust stroke. The magneto installation can be made on engines now in service without doing any machine work.

The engine with fixed-compression cylinder and water-pump is shown in Fig. 5. The condenser, pump and fittings have been designed so that they are interchangeable on both fixed and variable-compression cylinders. They can also be installed on engines now in service without any machine work.

A study was made of the spark-advance required for maximum power at various compression-ratios. The optimum spark-advance on the variable-compression engine was found to be almost directly proportional to the combustion-chamber height. Fig. 6 shows the curve for optimum spark-advance plotted against compression ratio, being the average of three runs made by hand setting. It also shows a curve directly propor-

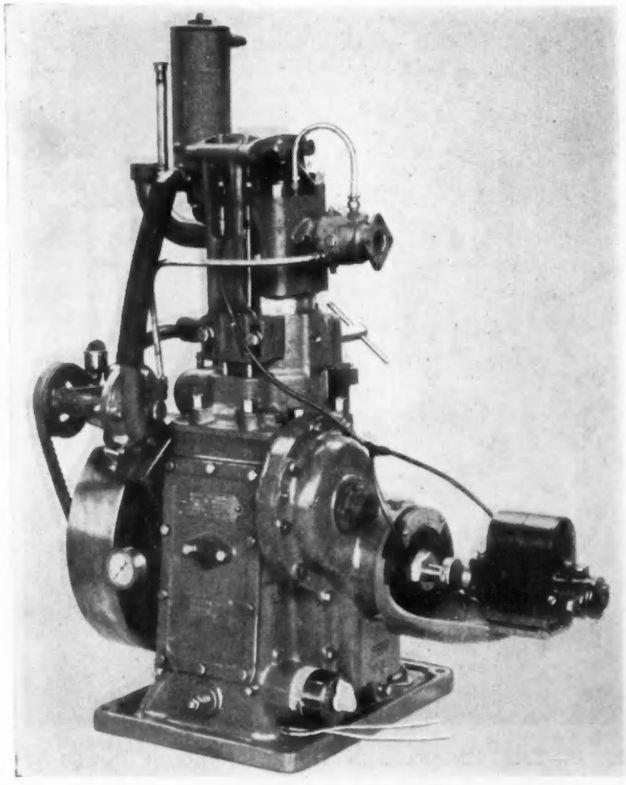

FIG. 4—A MODIFIED FORM OF ENGINE
This Unit Is Equipped with a Modified Centrifugal Type of Water-Pump and Magneto Ignition, the Latter Feature Providing a Uniform Spark-Intensity

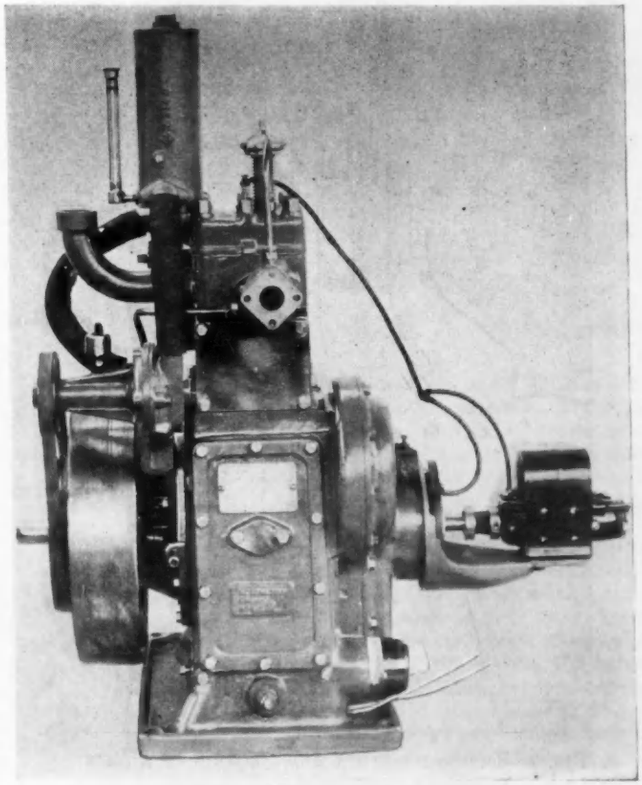

FIG. 5—MODIFIED ENGINE EQUIPPED WITH FIXED-COMPRESSION CYLINDER AND WATER-PUMP
The Condenser, Pump and Fittings Are Interchangeable on Both Fixed and Variable-Compression Cylinders

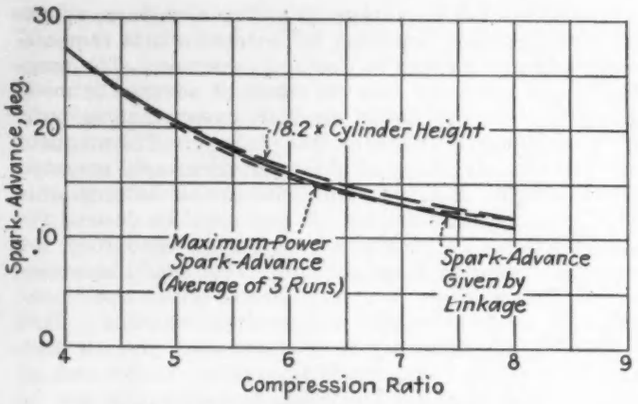

FIG. 6—SPARK CURVES FOR THE ENGINE

One Curve Is That for Maximum Power, Being the Average of Three Runs Made by Hand Setting; Another Is Directly Proportional to the Cylinder Height and the Third Is the Spark-Advance Obtained by a Direct Linkage between the Movable Cylinder and the Arm on the Breaker Box

tional to the cylinder height and a third curve that is the spark-advance obtained by a direct linkage between the movable cylinder and the arm of the breaker box.

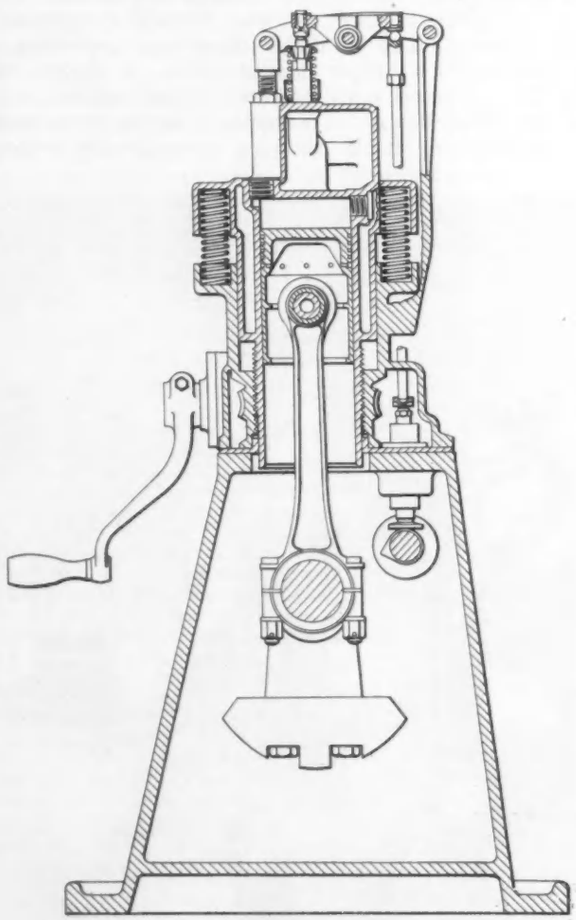

FIG. 7—DIAGRAMMATIC CROSS-SECTION OF A NEW VARIABLE-COMPRESSION CYLINDER

The One-Piece Construction Eliminates Gasket-Seal Unreliability, Cooling Difficulties and Spark-Plug and Bouncing-Pin Pockets, and Provides a Vertical Bouncing-Pin Position

A slight variation in the form of this last curve can be caused by adjusting the angularity between the breaker-box lever and the rod from the cylinder. This curve was made with the lever horizontal at 5:1 compression-ratio and 20.5-deg. spark-advance. The maximum variation between the spark setting given by the linkage and the optimum spark as determined by hand setting is about ½ deg. over the range from 4:1 up to 8:1 compression-ratio. This is within the limits of accuracy of the curve for hand setting.

The original variable-compression cylinder prompted several criticisms from various Committee members. The removable cylinder-head was subject to the unreliability of a gasket seal, complicated cooling, required a tilted bouncing-pin opening and resulted in the formation of pockets of considerable size between the ends of the bouncing pin and spark-plug and the combustion-chamber. The movement of the cylinder required too many turns of the hand crank and the cylinder rocked and vibrated up and down while it was being moved, necessitating clamping the cylinder before taking a reading. The valve gear was unsatisfactory since it was noisy in operation.

Fig. 7 is a diagrammatic section of the new variable-compression cylinder built to overcome these criticisms. Its one-piece construction eliminates the gasket unreliability, any cooling difficulty and spark-plug and bouncing-pin pockets, and gives a vertical bouncing-pin position. The lower end of the cylinder barrel is now finished to close limits on the outside and piloted in a guide member inserted between the crankcase top and the cylinder sleeve. The addition of this feature pre-

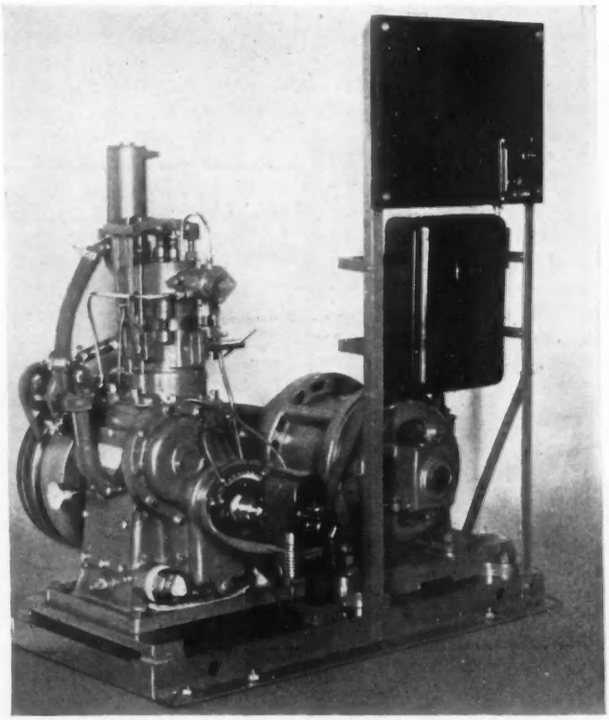

FIG. 8—THE ENGINE AND INDUCTION-MOTOR POWER-ABSORPTION EQUIPMENT

The Engine Illustrated Is of the Variable-Compression Type with the One-Piece Cylinder-Construction and Incorporates the Various Refinements of Design That Have Been Made. If Desired, the Fixed-Compression Cylinder Can Be Readily Substituted

vents rocking of the cylinder because of the great increase in length of the effective cylinder-guide. Four springs have been located in pockets between the cylinder and the sleeve to take up all vertical backlash while moving the cylinder. The speed of cylinder travel has been doubled by using 6 threads per inch instead of 12. Any tendency to develop looseness in the valve-clearance compensating-linkage has been overcome by eliminating the sliding pivot, shown in Fig. 3, at the cylinder end of rocker-arm carrier and substituting a fixed pivot. The necessary slight horizontal movement is now obtained by bending in the long vertical support, which has been made of thin section to allow this motion without undue bending stress. A ball-and-socket contactor has been provided at the end of the valve-stem as shown. It is supplied with oil through the hair filled pocket above. The valve-stems are now lubricated by a felt ring riding at the top of the guide which receives surplus oil from the ball-and-socket oiler above. A cup under the bottom of the valve-spring prevents the drippings from running away and supplies a certain quantity of oil by capillary action along the spring. The valve push-rod is now provided with a socket at its lower end to catch and hold oil.

Fig. 8 shows an assembly of engine and induction-motor power-absorption equipment. The induction motor is of the slotted-rotor type, so that it maintains a practically constant speed. This makes a very desirable automatic speed-control and relieves the operator of all effort in this respect. The engine is of the variable-compression type with the one-piece cylinder-construction, and it incorporates all of the refinements previously described. The fixed-compression cylinder can be substituted when desired. This engine represents the Committee's latest views on a standardized fuel-testing outfit, and it is hoped that future tests will warrant the making of formal recommendations on the part of the committee.

Knock Rating of Motor Fuels

(*Concluded from p.* 636)

minor importance compared with consistent behavior; and we presume that in this matter, as in all others where the final decision has yet to be made, the necessity for accuracy will be put before any considerations of simplicity of either technique or construction. Simplicity and accuracy do not invariably go together in such an instrument as a fuel-testing engine. Whatever the decision reached regarding the use of the variable-compression or the throttling method may be, the engines should be available with both arrangements when required, since many laboratories will be desirous of carrying out special investigations apart from any standard method that may be laid down.

The Anglo-American Oil Co. already has a Horning engine in its laboratory, and this is to be brought into line with the latest developments as soon as possible. The other two laboratories expect to have similar engines in a short time, and, as soon as these are installed, a further program of work will be arranged in collaboration with the Detonation Subcommittee of the Cooperative Fuel-Research Committee. Active steps are being taken to enlist the cooperation of other interested organizations in Great Britain and in Europe, and we hope that in the not far-distant future a considerable practical advance will have been made toward the international use of the standard engine.

Crankshaft-Vibration Dampers

SMOOTHNESS of engine operation is receiving much consideration. Lanchester dampers and dampers of other types have been given much attention, one of them being the rubber-mounted type which has the advantage of not being affected by the weather when it is mounted outside the crankcase. It is quite effective and consistent in its action.

In several cars the harmonic type of balancer, originally introduced on General Motors cars, has been combined with the Lanchester type. The resulting device has combined certain characteristics of the dynamic damper with others of the Lanchester damper with a very good result, as seen in the dampers used on Buick and Cadillac cars.

At least two manufacturers have attempted to improve the Lanchester damper by adding centrifugal control. Two vibration periods are likely to be troublesome in a six-cylinder or straight-eight engine; the third period is at such a low speed, say 30 m.p.h., that the damper setting required to control it is sometimes only about 20 to 30-lb. pressure.

At the fundamental vibration period, probably coming at over 70 m.p.h., a setting as high as 120 lb. is required to subdue the vibration. Several manufacturers have provided centrifugal dampers having a ring loaded with lead or with steel balls to cause expansion and increase the damper setting with the speed.

The number of crankshaft bearings seems to be increasing. Among straight-eight engines, 13 have nine main bearings, 21 have five and 8 have six. Among the sixes, 8 have seven bearings, 14 have four and 5 have three. However, the total number of engines built with the smaller numbers of bearings is greater than those with the larger numbers. The advantages claimed for the greater number of bearings are that it results in a stronger engine and allows the crankshaft to be made lighter.—From an Indiana Section Meeting paper by D. G. Roos, chief engineer of the Studebaker Corp. of America.

Status of Compression-Ignition-Engine Research

Annual Meeting Paper

By E. T. Vincent[1]

EARLY RESEARCHES on Diesel engines led to valuable practical results, one begun by a British Government department during the World War leading to the use of aluminum pistons and increasing the speed of submarine engines.

Many of the more recent fundamental researches failed to cover practical ground; for instance, the sizes of holes used in some injection research have been intermediate between those required for high-pressure injection and for precombustion-chamber engines. Work on centrifugal sprays has so far failed to materialize in practical service, but the author holds out hope for the future success of such sprays. Considerable practical experience is required as a basis for judgment in applying the results of such research.

Turbulence is one method of trying to make the Diesel engine realize its potential goal of developing higher power than a gasoline engine of the same displacement and speed by assuring the utilization of all the oxygen in the cylinder charge. Various designers attain virtually the same results with different degrees of turbulence and qualities of injection.

Detonation will become of increasing importance in Diesel engines, and presents an unworked field for research. A relation between time lag and detonation is reported.

The author concludes that too much should not be expected from fundamental research in a short time and that it will in the future make available fundamental data of great value in practical design.

ENORMOUS strides in the amount of fundamental research work conducted upon the problems related to the high-speed compression-ignition engine, often erroneously termed the Diesel engine, have been seen during the last few years, and many data have already accumulated. A lively interest in fundamental research is of great advantage to any industry but, in common with all new subjects, considerable effort is wasted because many investigators lack the practical experience of the necessary requirements to direct their inquiries along lines most advantageous to the industry concerned. It is wise therefore to pause occasionally to review the position and relate it, if possible, to the practical side of the art; and I will attempt such a revision in the case of the compression-ignition engine, pointing out the divergencies between the methods and apparatus used by the scientist and those employed in practice.

Such fundamental research on oil-engine problems has been conducted by various government establishments and universities. Perhaps the earliest of these was that sponsored by the British Government during the World War, about 1916, which resulted in the formation of the Admiralty Engineering Laboratory for the primary purpose of studying the oil engines then fitted to submarines with particular reference to cleaning up the exhaust gases, increasing power and speed, and generally improving the performance of these craft. This establishment therefore directed its efforts mostly to the practical problems involved, to meet the urgent war-time needs, but some experiments upon such subjects as spray formation and penetration were undertaken. The general results were increasing the speed up to about 600 r.p.m., a high speed at that time; increasing the brake mean effective pressure; and reducing considerably the fuel consumption, with better operation. Incidentally, perhaps the first aluminum piston for a Diesel engine was developed, very satisfactory performance being secured.

The problem was then taken up by the British Air Ministry, which designed and tested a light-weight compression-ignition engine operating at 1200 r.p.m. The results secured were such as to stimulate thought and action throughout the world, resulting in the present activities. Research work upon this problem was undertaken in this Country by the National Advisory Committee for Aeronautics, Pennsylvania State College and others. Several valuable pieces of apparatus have been developed, from which information of undoubted value has been secured, and several points about the behavior of jets are now definitely explained which could only be guessed at previously.

The great need of the industry at present is knowledge of the methods to be used in designing efficient injection systems and combustion-chamber shapes to cause a greater percentage of the air charge to take part in the combustion process and thus to realize the potentially high power output of the oil-engine cycle. Theoretically, a compression-ignition oil engine is capable of a higher power output than a gasoline engine, but means have yet to be found to achieve this. Let us examine the published literature upon injection and combustion, to form some idea of how far the research worker has helped practice toward achieving this end at present.

Injection Researches

The National Advisory Committee has developed a spray-photography apparatus, and the penetration and other properties of oil jets have been examined, but a study of these tests and comparison with practical requirements indicate that their field of usefulness is rather restricted. A few selected cases may be examined by way of illustration. First, consider the co-

[1] Diesel research engineer, Continental Motors Corp., Detroit.

efficients of discharge for small holes. In this investigation, as reported by W. F. Joachim[2], the value of this coefficient was determined for holes of 0.015, 0.020 and 0.025-in. diam., when discharging Diesel-engine fuel into the atmosphere from pressures up to 8000 lb. per sq. in. Some very interesting results were obtained, but consider the position of a designer of automobile or aeronautic engines who wishes to know something of this matter. The diameters of the holes employed in these experiments are not small enough for a constant-pressure injection system and not large enough for a precombustion-chamber engine.

Experiments upon penetration of oil jets at high speed from a fuel system approximating that of the constant-pressure type were conducted and reported by H. Miller and E. Beardsley[3]. The diameter of the hole used in this case was 0.015 in. As before, this is too large for this type of system. It is chiefly upon size, number and arrangement of the holes that the engine results depend, as these are the factors that control results such as penetration and distribution. Taking into account all the factors such as piston diameter, stroke and speed of rotation, a 0.015-in. hole would require approximately a 10-in. cylinder to make possible satisfactory combustion. This size takes an engine out of the high-speed class, for both aeronautic and automobile uses. Is it possible, then, to apply these results to the slower-speed engines such as are used for generators, yachts and similiar installations of relatively large power? In such cases, the maximum speed would be of the order of 500 r.p.m. and the injection interval probably would be 0.015 sec.; hence the study of the N. A. C. A., covering a period of only 0.005 sec., shows but little of the events occurring during the injection period, restricting the usefulness of the data supplied.

Centrifugal Sprays Do Not Fulfill Promise

Considerable time and energy were devoted at Langley Field to the study of centrifugal sprays[4]. Their action is excellent in theory. Even when sprayed into compressed air, their atomization and distribution seem far superior to those of the ordinary spray. Many persons advocate them before obtaining actual experience with them in an engine. I also went through this stage during the experiments already referred to, conducted by the British Admiralty, and used centrifugal sprays of many types. I collected considerable information upon their characteristics, from which what might be considered a perfect spray was built up and designed into an actual injector valve and engine tests were conducted. The results were a dismal failure and, despite all attempts at improvement, this type of spray had to be abandoned. The same can be said of all subsequent attempts with which I am acquainted.

It does not follow that the analysis of centrifugal sprays referred to was a waste of time. I believe that eventually they may play a very important part in achieving the high mean pressures desired for the small high-speed engine. My intention is to warn investigators against trying to apply these data to practice without looking deeper into the subject. Undoubtedly the National Advisory Committee intends to extend its activities into the practical field, and in fact has already done so to some extent. It is quite possible that the correct combination of combustion-chamber, turbulence, penetration and other variables will be determined at Langley Field, and the advantages of centrifugal sprays, such as large hole-size, simplicity of construction and low injection pressure for a given atomization, may be secured.

Similar criticism can be directed against many other investigations upon the spraying of fuel; but, because they are so widely known, the N. A. C. A. reports were selected to illustrate the point that it is necessary for a designer to have considerable practical experience with oil engines and their operation before attempting to apply these results to practice. The National Advisory Committee is to be congratulated upon the manner in which it has conducted these researches and deserves the thanks of the industry as a whole. It is too much to expect that the solution of all the problems of such a subject as that under consideration will be achieved in a year or so. Time will result in a gradual increase in the available knowledge, and the N. A. C. A. is placed in such a position that we can look to it to be the chief source of supply of such data.

Some Combustion Researches Wide of the Mark

Consideration can now be given to experiments to determine the actual combustion time of a charge injected into heated air. In this case greater variations than ever exist, and it is necessary for some authority to examine the results carefully and try to relate the various experiments and determine what are the essentials underlying the available data. To quote one or two cases, there are the results of A. L. Bird[5], who originally obtained ignition within 5 in. of the nozzle when spraying into air at a temperature of 825 deg. fahr. I believe that subsequent work by the same author has resulted in this distance being reduced to approximately 1 to 1½ in. Dr. Wilheim Riehm[6] deduced from his investigations that ignition does not set in until the fuel has travelled 12 in. from the nozzle, while P. H. Schweitzer[7] states that combustion begins almost instantaneously but is not completed until about 12 in. from the nozzle when injecting at 4000 lb. per sq. in. into air at 200 lb. per sq. in. with a 0.025-in. nozzle.

These great differences need some explanation. The accuracy of the experimenters is not doubted and, to connect the results, it remains to consider the apparatus used and the conditions of the tests. For example, Bird's temperature corresponded to a compression ratio of only 9:1 instead of about 13:1, therefore combustion in the engine would occur much faster than in these tests. Schweitzer's results, also, are open to criticism because of an injection orifice too large for a constant-pressure or jerk-pump system and too small for a precombustion engine. Similar explanations can be found for most of the discrepancies between theory and practice.

A little actual experience in oil-engine operation will soon show that contact of unburned fuel with any metal surface must be avoided at all costs. Because of this, the jet travel between the nozzle and piston or wall is the limiting distance for complete combustion. In a normal, efficient combustion space for a 15-in. diameter cylinder, the distance between the nozzle and the piston

[2] See National Advisory Committee for Aeronautics Technical Report No. 224, 1925.

[3] See N.A.C.A. Technical Report No. 222, 1925.

[4] See N.A.C.A. Technical Reports Nos. 258, 268, 274 and 281, 1927.

[5] See *Proceedings of Institute of Mechanical Engineers*, No. 5, 1926, p. 955.

[6] See *Zeitschrift des Vereines Deutscher Ingenieure*, vol. 68, 1924, p. 641.

[7] See *Transactions of the American Society of Mechanical Engineers*, OGP-52-15, September-December, 1930.

on the line of spray is not more than approximately 4 in., so that results such as 5 to 12 in. of travel before ignition are obviously off the mark. Ignition within a very small distance of the jet must be assumed to explain the combustion problem of a high-speed oil-engine with any degree of satisfaction. If experimental results do not fulfill this condition, the apparatus and conditions should be analyzed to find the cause.

Fundamental research only has been considered in the foregoing. There remains the wide field that can be called industrial research, which represents the attempts to translate theory into practice. Here again wide differences of opinion exist, and it is well that they do; otherwise progress would suffer. All workers in this field are endeavoring in one way or another to improve engine performance, and the somewhat conflicting lines of thought have resulted in certain well-defined types of engine, each suitable for a particular type of duty. I propose to consider the relative merits of these for automobile and aeronautic purposes, which are the two branches of engineering in which the members of this Society are chiefly interested. I shall devote my attention to the actual performance of engines having different types of injection and combustion systems, rather than to their various advantages and disadvantages regarding which so much has recently been written.

Turbulence Depends upon the Injection System

Consideration of both experimental and practical compression-ignition engines of all types indicates that one of the main differences between them is the way in which turbulence is produced and utilized to assist combustion. Turbulence has been advocated by some authorities as the cure of all combustion ills of the gasoline engine, while others express somewhat the opposite view. The same can be said of the compression-ignition engine.

Exponents of the turbulence theory usually aim for rotary air swirl at some definite rate which will distribute the fuel throughout the air in an efficient manner. Experiments conducted by the writer utilized various velocities of rotational swirl, and careful examination of the combustion-chamber after tests failed to reveal any deflection of the oil jets. Very faint marks usually are visible upon the piston crown opposite the oil jets. It was impossible to change these markings by quite a high rotary swirl from the position they occupied when no definite turbulence was attempted. It is quite possible that some dispersion of the finer oil particles occurred, but apparently the main body of the injection was undisturbed. Against this must be set the fact that Ricardo has demonstrated in no uncertain way that controlled turbulence can be relied upon for efficient combustion in a compression-ignition engine. An attempt will be made to reconcile some of these results.

Ricardo utilized a single-sleeve-valve engine and was able to control the degree of rotational swirl at the end of the compression stroke by means of guides in the inlet port and a restriction in the combustion-chamber. Fuel is fed into this rotating mass of air by means of a plain large-hole open-ended injector directing the fuel parallel to the axis of the cylinder and situated out toward the wall of the combustion-chamber, as shown in Fig. 1. If this engine were run without the turbulence, its power output and fuel economy would be very poor. Improved performance would result as the turbulent effect was increased, up to a certain value of the rotary swirl. Beyond this point the results fall off again, indicating that it is possible to cause excessive turbulence.

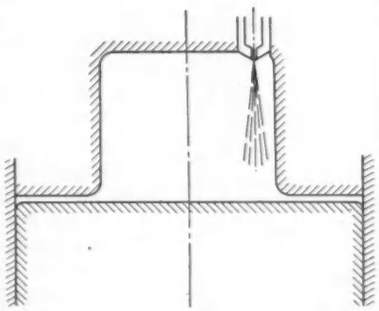

FIG. 1—COMBUSTION-CHAMBER OF RICARDO SLEEVE-VALVE ENGINE

Hesselman produces rotary turbulence by deflectors at the inlet valves, and improved results are claimed for a definite degree of rotation. The engine with which I experimented showed no improvement at all from the application of rotary swirl. If the power output and fuel economy of these three engines are compared, it is seen that they all perform approximately the same at a fuel consumption of 0.38 lb. per b.hp-hr. and 100 lb. per sq. in. b.m.e.p. Ricardo started with a very poor injection system and reached certain results by turbulence; Hesselman started with a medium injection system and was able to improve the results by turbulence; while my tests were made with careful attention to the injection system itself, and the indiscriminate turbulence due to the valve action in conjunction with the spraying and distribution of the fuel was sufficient to produce excellent combustion.

This illustrates how several lines of thought will be put forward, each claiming the same achievement. Each experimenter will be right, but only within the limited conditions of his tests. It will remain to be proved which is the best manner of overcoming the various difficulties. Ricardo's method seems to be applicable only to sleeve-valve or two-cycle engines, while the advantages of the Hesselman system seem very doubtful, since it requires all the elements of an efficient high-pressure injection system which can quite readily be made to give excellent results without turbulence. Rotational swirl of the Ricardo type undoubtedly simplifies the injection system, since the pressures to be carried are much lower; but the need for accuracy of measurement of the charge still exists, and this is more difficult than high pressure. It has been demonstrated that high pressure alone is no disadvantage. The performance of some high-speed rail-car oil engines which have run as much as 150,000 miles without repairs to their high-pressure pumps can be cited in support of this.

Engines now being manufactured can be divided into three groups: (*a*) direct-injection, (*b*) precombustion-chamber and (*c*) divided combustion-chamber engines.

Direct-Injection Engines

The essential peculiarity of the direct-injection engine is that the oil is injected under high pressure directly into the combustion-chamber formed between the piston and the cylinder-head. The performance of this type is excellent and the specific output is high, brake mean effective pressures as high as 125 lb. per sq. in. being maintained. The fuel consumption is low, 0.35 lb. per b.hp-hr., and starting is easy in the coldest weather without heaters or abnormal compression pressure. The

speed range is good, and torque is maintained virtually constant at all speeds.

Its chief disadvantages are the high injection pressure, though the difficulties of this have been greatly exaggerated; the small diameter of the spray holes; and some difficulty in securing an absolutely smokeless exhaust, despite the very low fuel consumption recorded. This last fact, however, seems to be of some benefit, since engines of this type will run efficiently so long as the valves are in good condition, decarbonizing being unknown, the carbon apparently being rejected to the exhaust. Sixty thousand miles and up of operation under high load factors is common with engines of this type without decarbonizing, valve grinding or the use of carbon solvents.

The objections raised against the small holes of this fuel sprayer are based, to some extent, upon fact; but was not the same true of the gasoline engine some years ago? Eventually the oil companies paid careful attention to the filtering problem and effective filters are installed on the engine, so that choked carbureter jets are almost a thing of the past. With increasing demand for a heavy oil for vehicles, it will be necessary for the refiner to pay the same attention to filtering the heavy fuel as in the case of gasoline. Effective engine filters can go a long way even with the present fuels, and I know of many cases in which it is necessary to clean sprayers of this type only after approximately 10,000 to 15,000 miles of operation.

It is often stated that the direct-injection engine is very sensitive to the fuel used. This may be the case in some instances, but the figures of Table 1 indicate that such an engine can be built to deal with a wide range of oils. Speeds up to 2000 r.p.m. have been used with this system.

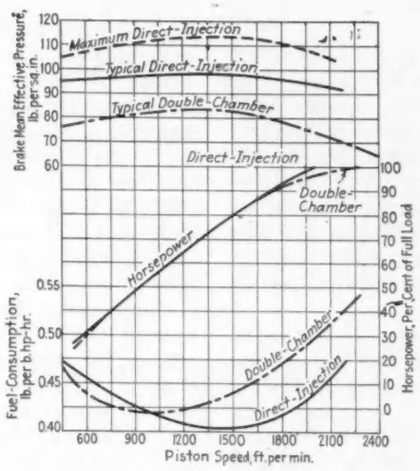

FIG. 2 — TYPICAL CURVES OF DIRECT-INJECTION AND DOUBLE-COMBUSTION-CHAMBER ENGINES

A Maximum Curve of Brake Mean Effective Pressure for the Direct-Injection Engine Is Shown in the Dotted Line at the Top. Other Curves for Direct-Injection Engines Are in Full Lines, and Curves for Double-Chamber Engines Are in Dot-and-Dash Lines

TABLE 1—TESTS OF ENGINE WITH VARIOUS FUEL OILS

	Anglo-Persian Diesel Oil	Shell Mexican Diesel Oil	Gas Oil	Boiler Oil
Specific Gravity at 60 deg. fahr.	0.835	0.844	0.869	0.926
Flash-Point, deg. fahr.	212	166	171	126
Viscosity, Saybolt, sec.	35 at 60 Deg.	83 at 70 Deg.	50 at 70 Deg.	1850 at 70 Deg.
Water, per cent	Nil	0.10	Nil	Nil
Asphalt, per cent	Nil	3.6	0.30	5.60
Ash, per cent	Nil	Negligible	0.03	0.02
Sulphur, per cent	0.22	1.6	0.50	0.67
Calorific Value, B.t.u. per lb.	19,716	19,383	19,433	19,060
Engine Speed, r.p.m.	719	720	721	720
Brake Horsepower	192	192	192	192
Fuel Consumption, lb. per b.hp-hr.	0.388	0.408	0.406	0.422
Fuel Consumption, lb. per b.hp-hr.[a]	0.403	0.416	0.415	0.424

[a]Corrected to 19,000 B.t.u., per lb.

Precombustion-Chamber Type

Characteristics of precombustion-chamber engines are: relatively low mean effective pressure at full load; poor fuel economy, when compared with the direct-injection system; difficult starting, even with high compression-ratios, auxiliary heat being necessary at all atmospheric conditions; and relatively frequent decarbonization despite the fact that a clear exhaust is readily obtained. A low-pressure injection system is used and a relatively large-hole spray valve. Claims are made for satisfactory engine performance with a wide range of fuel.

The torque curve from an engine of this type approaches the shape of that of a gasoline engine instead of the approximately straight line of the previously considered system. The heat flow is more severe, because of the redued fuel economy, but the economy is still superior to that of a gasoline engine.

The chief claim for this type of engine is simplicity of the injection apparatus, but it is doubtful if this can be substantiated in actual practice. A comparison of the actual details with those of the high-pressure type reveal little if any difference. Lapped fits of plungers and other parts are necessary, despite the lower fuel pressure. The net result is that considerable sacrifice in performance has been made to obtain a large spray hole.

The popularity of the precombustion type of engine has undoubtedly extended its use far beyond its merits. It originated at a time when medium-speed and medium-duty engines were required and high-duty high-speed oil engines were still considered almost an impossibility. Extensive research work resulted, particularly in Germany, in engines of the precombustion type. As a result, it has been far easier for companies unacquainted with the Diesel to extend this engine to higher speeds than to begin a design of their own, despite the demonstration by the Royal Aircraft Establishment of the far superior performance of the direct-injection system.

The low specific output results in abnormal size and weight for a given power, and it is considered that this engine has only very limited possibilities as an automotive engine, despite the fact that some modern engines of this class are operating at 2500 r.p.m.

Divided Combustion-Chamber

There are a number of engines which represent an intermediate ground between the direct-injection engine and the precombustion type. In this type, the combustion-chamber is divided into two compartments, one formed between the piston and cylinder-head, and the other a separate chamber connected with the first by a relatively large throat. Fuel injection occurs in the separate chamber or in the throat joining the two, and the gases expanding into the cylinder during the expansion stroke create the necessary turbulence for combustion.

The claims for this engine are similar to those for

the precombustion engine; namely, large spray orifice and low fuel pressure, good turbulence, and ability to burn a wide range of fuel.

The performance of this type of engine, as would be expected, is intermediate between the direct-injection and the precombustion-chamber type, approaching that of the former as the ratio of air in the cylinder at top dead-center to that in the auxiliary chamber is reduced, but the details of the injection system must be improved as this ratio is reduced, until the engine approaches the direct-injection type.

Fig. 2 records typical performance curves of a direct-injection engine and a double-chamber engine which approaches that of the precombustion-chamber type. For the present purposes these latter curves can be considered to represent the performance of either the double-chamber or the precombustion system. The increased specific output of the direct-injection engine is apparent. The curve representing the maximum output for this latter type is quite conservative and many engines tested by the author readily carry up to 125 lb. per sq. in. b.m.e.p.

Summing up the position with reference to the injection system, the author considers that for automotive purposes the compression-ignition oil engine of the future will be of the direct-injection type, or some modification of this, to secure the advantage of low weight per horsepower, easy starting in all weathers, wide fuel range and high fuel economy. A four-cycle engine of this type should weigh 15 to 20 per cent more than an average gasoline engine operating at the same piston speed. If the two-stroke cycle is employed, as no doubt it eventually will be, its power:weight ratio will be superior to that of a gasoline engine.

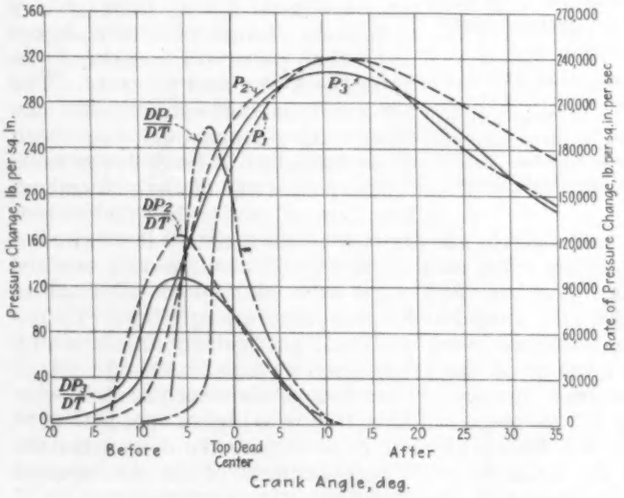

FIG. 3—EFFECT OF COMPRESSION ON COMBUSTION

Curves for a Compression Pressure of 400 Lb. per Sq. In. Are Designated by P_1; 420 Lb. Per Sq. In., P_2; and 440 Lb. per Sq. In., P_3

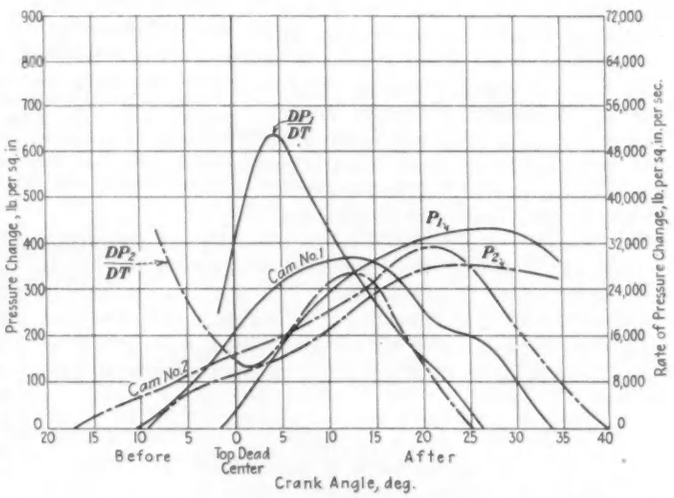

FIG. 4—EFFECT OF RATE OF FUEL SUPPLY ON COMBUSTION

Detonation Is Relatively Harmless

Evolution of the high-speed high-duty compression-ignition engine probably will bring the subject of detonation to the fore. Detonation in compression-ignition engines is not accompanied by any of the serious consequences that are associated with it in the gasoline engine. In fact, detonation is usually accompanied by an all-round improvement in operation and is objectionable only because of the resulting noise and the rapid rate of loading the bearings. The maximum loads of the engine are not affected, but solely the rate of application of the load; for example, it is possible to have one engine with a maximum pressure of 600 lb. per sq. in. accompanied by very heavy detonation while another may run with a maximum pressure of 900 lb. per sq. in. and no trace of detonation. Summarizing the available experiments upon this subject, the chief points of interest are as follows:

Increasing the compression pressure eliminates detonation in the injection engine, instead of producing it as in the gasoline type. This result has been observed on two-stroke and four-stroke engines with both air-blast and mechanical injection systems and is considered to be characteristic of all oil engines. This observed fact can be explained theoretically in the following manner:

Combustion diagrams obtained from various engines proved that detonation is a function of the rate of change of pressure occurring during the approximately constant-volume-combustion portion of the cycle, and that it also is dependent upon the time lag between injection and combustion. The latter fact suggests that fuel which is still being supplied by the injector during the lag interval accumulates in pockets of combustible mixture which may detonate the same as a gasoline mixture if the time lag is sufficient.

Increased compression shortens the combustion lag. This should result in reduced mixture formation and therefore reduced detonation. If this is the case, a decreased rate of fuel supply at a constant injection pressure should reduce detonation. Actual tests conducted to verify this assertion have demonstrated the point.

The curves of Fig. 3 indicate the effect of compression pressure upon the rate of change of pressure. The curves marked P_1 represent conditions under which considerable detonation was occurring, while there was none in the other cases. Fig. 4 shows the effect upon the rate of change of pressure from slowing up the rate of fuel injection. Further information upon this subject may be found in a paper[8] by Leigh M. Griffith and

[8] See *Transactions of the American Society of Mechanical Engineers*, AER-52-5, January-March, 1930.

me which was read at the A. S. M. E. aeronautic meeting at St. Louis in 1930.

Experience and Research Will Work Together

The published fundamental research upon the problems of the compression-ignition engine is not yet in a sufficiently advanced stage to be of great help to the practical worker who has not had considerable experience in the field of oil-engine development. As this type of engine becomes more widely known and our knowledge of injection and combustion improves, it will be possible to predict engine performance with greater accuracy than is now possible with the gasoline engine, because direct control upon the combustion process should be possible at almost all stages.

Subsequent research work will undoubtedly clear up many of the discrepancies between the various experimenters of today, and, as actual experience with the injection engine becomes common, the pure-research worker will be able to reconstruct actual engine conditions with greater accuracy.

It is concluded that there are as many right ways of applying turbulence as there are injection systems, each set of conditions demanding its own degree of turbulence, but that eventually the present great diversity of systems will gradually disappear and development will proceed along two or three well-defined lines.

The future compression-ignition engine for automotive applications will embody the direct-injection fuel system in its present or more probably in some modified form that will contribute to the construction of an engine of high power output for a given weight. This weight should not be more than 10 to 15 per cent above that of a corresponding gasoline engine of the same class and, as subsequent progress is made toward the utilization of the air content of the cylinder, the weight per horsepower of an oil engine should trend toward being less than that of the present gasoline engine.

Production of high-speed high-duty compression-ignition engines will make the question of detonation more prominent than it has been, and here is a wide field, now almost unbroken, for the research worker.

THE DISCUSSION

ROBERTSON MATTHEWS[9]:—Some of the research work done by the National Advisory Committee for Aeronautics, with which I was connected at about the time the work under discussion was done, was not intended to be shop research or design research. While it was not what is known as pure research, it was more nearly that than design research. Critics of this work seem to misinterpret it in that respect. A need is evident for wider cooperation in Diesel-engine research, such as is being practiced by those who are making a study of detonation.

Diesel-engine designers are divided into two schools, according to whether or not they believe that vaporization of the fuel is necessary. Those who are working with large slow-speed engines for marine or stationary service are not restricting the development of their own engines in believing that vaporization is not needed. While I admire the work that they have done and believe that it will never be fully appreciated, conditions in high-speed engines differ from slow-speed operation just as much as spreading Duco differs from spreading gold-leaf.

ROBERTSON MATTHEWS

I have been told that the Acro engine is subject to late burning. Time is a vital factor in high-speed engines. Carbon will burn, but gasoline burns faster and hydrogen burns faster still. I look forward to seeing some investigation of regulation of the timing of compression ignition.

Carbureter engines now seem to be superior to compression-ignition engines both in speed and mean effective pressure. It has taken about 15 years to make an increase of 1000 r.p.m. in the speed of the compression-ignition engine. If 15 years more is required for the next 1000 r.p.m., we may be sailing under another flag by that time.

Much could be said on the subject of vaporization, but I wish to emphasize here that a distinction must be made between high-speed and low-speed engines. Even coal dust can be burned in a low-speed engine, but the best fuels are required for high-speed engines.

Questions Utilization of Low-Grade Fuels

Engineers who are interested in attempts to widen the field of the high-speed compression-ignition engine will find significant statements in a paper by Robert E. Wilson[10]. Such statements from executives in the oil industry are at least as significant as are the wishes of the sales departments in the engine industry. I suggest consideration of the following additional questions:

(1) If gas oil is preferred to fuel oil for engines running at 300 r.p.m., is it unreasonable to demand something better than gas oil for engines that are to run at 3000 r.p.m.?

(2) In this day of chemistry, why should a mechanical engineer be asked to do with fuel in an engine, almost blindly and drop by drop, what a chemist could do better by the tank-full?

(3) Fuels such as some people would have us use will never be tolerated in large quantities on busy thoroughfares. Fuels and concoctions, the provision of which has cost millions of dollars, have been provided for carbureter engines; why should any body of engineers be called upon to utilize in engines of like speed or size what is relatively a residue?

(4) Would any member of the Society care to be seen on the highway trying to start an ordinary gasoline engine on straight kerosene? How many decades must pass before we shall look equally askance at engineers who are trying to use gas oil in 3000-r.p.m. engines intended to compete with gasoline engines?

[9] M.S.A.E.—Research and development engineer, Detroit.

[10] See S.A.E. JOURNAL, January, 1931, p. 93.

(5) Are we expected to use fuel of this sort in compression-ignited engines because of insistence upon the term "Diesel"? The Diesel engine gained its reputation by its ability to burn residual fuels and to attain unsurpassed thermal efficiency. The primary aim of engineers working on high-speed engines is not to create a costlier engine having the characteristics of a fuel incinerator but to create a cheaper engine having a higher thermal efficiency.

Diesel engines have been imported for use in motortrucks and motorcoaches. Is it not time for us to develop high-speed engines that are not based on attempts to meet the European fuel situation but to meet the native American fuel situation? To that end it might be well that hereafter the name of no man should be attached to any high-speed commercial engine to designate its type and that we form an Activity of the Society to be known as the Advanced Engine Development Activity.

One of our present troubles is that we cannot see what is happening in the engine. We are in relatively the same position as was Watts in understanding what transpired inside the steam-engine cylinder. I propose that someone who is sufficiently interested should offer a sum like $25,000 or $50,000 as an incentive for the development of a combustion indicator.

A. M. ROTHROCK

Fuel Spray Can Impinge Hot Surfaces

DR. P. H. SCHWEITZER[11]:—My discussion of this paper will be restricted to the correction of a few statements that are known by me to be incorrect.

The experiments on nozzles at the Pennsylvania State College were conducted with orifices from 0.007 to 0.040 in. and the National Advisory Committee for Aeronautics I believe used still smaller orifices. No commercial orifices in use are as fine as those investigated. True, few of the test results reported refer to nozzle orifices of the size in which the author is most interested, but a number of practically important spray characteristics do not depend primarily on the orifice diameter. It has been shown that, in the region of good atomization, neither cone angle nor penetration is greatly affected by the orifice diameter.

According to the author, I have stated that "combustion begins almost instantaneously but is not completed until about 12 in. from the nozzle . . ." I have made no such statement.

The author is misinformed when he states that "contact of unburned fuel with any metal surface must be avoided at all cost," obviously referring only to contact inside the combustion-chamber. Precombustion-chambers, hot-plates and piston-heads are regularly impinged upon by the fuel spray with no harmful effect. This is fortunate, because it is next to impossible to keep the fuel spray away from the piston. Many builders accentuate the impingement of the spray on the piston-head. Krupp uses a mushroom impingement-plate. Provision for spray impingement is also made in the Packard piston. Not many engines have ever been built in which the spray absolutely avoids hitting metallic surfaces. Most of us are perfectly satisfied if the oil spray strikes no metallic surface which is cooler than say 1000 deg. fahr. Cracking, with carbon deposition on the surface, occurs in the range of approximately 700 to 1000 deg. fahr. Above the latter temperature, however, the carbon burns as soon as it is formed, and an impingement of the spray on such a hot surface is not objectionable. If this were not so it would be almost impossible to build Diesel engines in sizes less than 100 hp. per cylinder, because the spray is longer than the room available.

The author seems to expect from the rotary air swirl something that the users of this method did not intend to obtain. It is well known that a strong oil-jet is not deflected by a moderate wind. The purpose of the rotary turbulence is to bring fresh air to the fuel spray while the combustion is in progress. This is apparently achieved. The rotary turbulence was used with good results, not only in sleeve-valve and two-cycle engines, but in four-cycle poppet-valve engines made by Hesselman, Krupp, De La Vergne, and others.

I should like to know whether the author's figures for mean effective pressure and fuel consumption refer to brake or to indicated horsepower.

Research on Practical Orifice Sizes

A. M. ROTHROCK[12]:—Mr. Vincent has stated that in the research conducted by Mr. Joachim the coefficients of discharge of fuel-injection nozzles are not applicable to high-speed automobile and aeronautic Diesel engines because the smallest orifice investigated had a diameter of 0.015 in. Orifices of 0.020 and 0.030 in. have been used successfully on high-speed Diesel engines, as reported by H. Ricardo[13] for a 5½-in. cylinder and by J. A. Spanogle and H. H. Foster[14] for a 5-in. cylinder.

Examination of the spray-photography data presented by the National Advisory Committee for Aeronautics shows that diameters as large as these are necessary if penetration to a distance of about 4 in. is to be obtained in the short time available. Apparently Mr. Vincent is not acquainted with the data on the coefficient of discharge which is being published by A. G. Gelalles[15]. Preliminary reports on the results of these tests have been given by Carlton Kemper[16].

Results of Mr. Gelalles' work lead to the important conclusion that—with orifice diameters such as he investigated, 0.008 to 0.025-in.—the coefficient of discharge is independent of the orifice diameter if the orifices are made geometrically similar and the flow through them is turbulent; or, if the flow is laminar, the Reynolds numbers for the conditions are the same. Mr. Vincent seems not to be familiar with other of the more recent work of the N. A. C. A. in connection with fuel-spray research. Considerable material has been published[17] during the last two years in regard to orifices as small as 0.006 in.

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[11] M.S.A.E.—Associate professor of engineering research, Pennsylvania State College, State College, Pa.

[12] Associate physicist, National Advisory Committee for Aeronautics, Langley Field, Va.

[13] See *Aircraft Engineering*, (English), May, 1929, p. 82.

[14] See N.A.C.A. Technical Note No. 344, June, 1930.

[15] See N.A.C.A. Technical Report No. 373 (to be published).

[16] See *Transactions of the American Society of Mechanical Engineers*, OGP-52-5, May-August, 1930, vol. 52, No. 20.

[17] See N.A.C.A. Technical Notes No. 329, December, 1929; No. 338, May, 1930; No. 352, October, 1930; No. 356, November, 1930.

A clearer understanding of centrifugal sprays can be obtained by referring to the work of Dr. R. Kuehn[18], in addition to the work done by the Committee. He has shown that centrifugal sprays do not give, for equal injection pressures, better atomization than the sprays from plain orifices. Mr. Gelalles has shown[15] that, with the same injection pressure, considerably less fuel is injected through a valve having a helically grooved stem than through one having a plain stem. Consequently, we cannot expect the centrifugal spray to give good engine performance unless used with much higher injection-pressure or larger orifices than are required for plain sprays. The centrifugal sprays have not yet been given a fair trial. We can definitely say that centrifugal force does not improve the atomization of the spray, but it may improve the distribution.

Effect of Air-Flow Studied

Preliminary material on the effect of air-flow on fuel sprays has been published by E. G. Beardsley and myself[19]. Little change was made in the fuel spray during injection by air-flow of the low velocity of 60 ft. per sec., but the fuel was quickly distributed throughout the chamber by the air when the injection was cut off. Tests are now being made with air velocities as high as 600 ft. per sec. These tests show that it is possible to deflect the main body of the spray from single round-hole orifices only with air at a very high velocity, but lower velocities will force fuel away from the edge of the spray. Certainly the results obtained by H. Ricardo[13], K. J. E. Hesselman[20] and Carlton Kemper[21] demonstrate that air-flow in the combustion-chamber improves the performance. Messrs. Spanogle and Foster[14] have shown, on the other hand, that good performance can be obtained with a quiescent combustion-chamber.

I would not go so far as to say that the researches on combustion are wide of the mark. This probably is the most difficult phase of the problem to be investigated. It is natural to expect that the first researches should be done under conditions that are quite different from the actual conditions in an engine; but if we follow through the work done by Harold Moore[22], C. J. Hawkes[23], J. Tausz and F. Schulte[24], Kurt Neumann[25] and A. L. Bird[26], we notice that test conditions are approaching the conditions encountered in the engine. The most recent results presented by Mr. Bird at the Third International Power Conference in Berlin showed that the apparent discrepancy in the time-lag of combustion was caused by the air-fuel ratio employed by the earlier investigators. Using ratios comparable with those obtaining in the engine, Mr. Bird has determined an ignition lag of 0.004 sec., which is comparable with the lag in an engine.

I appreciate papers of the type presented by Mr. Vincent. It has always been beneficial to the research worker to have criticism of his work by men connected with the industry, for it is by this method that the necessary cooperation between the research worker and the manufacturer can best be obtained.

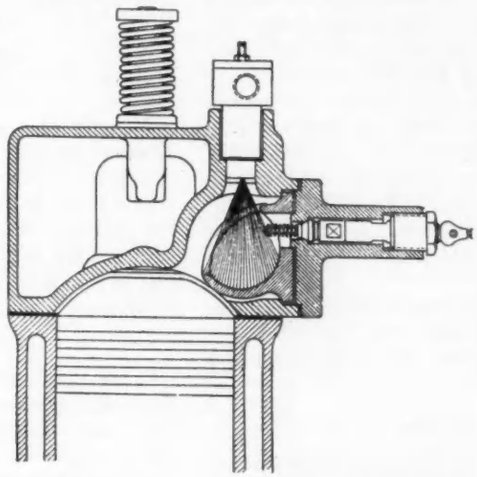


FIG. 5—COMBUSTION-CHAMBER OF OBERHAENSLI ENGINE

Injection Is from the Plug at the Top. A Glow Plug, Shown at the Right, Is Provided for Starting

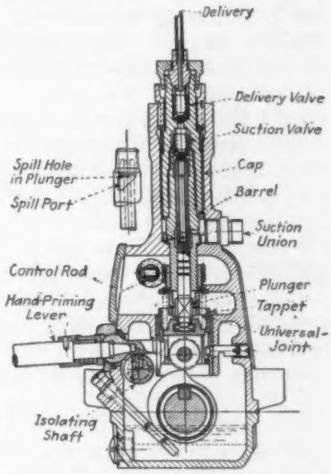


FIG. 6—CROSS-SECTION OF REF FUEL-PUMP USED IN OBERHAENSLI ENGINE

A Recent Austrian Diesel Described

WOLFGANG VON DORRER[27]:—One of the latest European engines is the Oberhaensli, built in Bregenz, Austria. The combustion-chamber of this engine, shown in Fig. 5, is a compromise between the precombustion-chamber and the air-chamber types. By means of a shell, which is suspended in the combustion-chamber, the compressed air is divided into two highly turbulent streams. The fuel is injected into the suspended shell. There it vaporizes and burns partially, bringing the mixture into close contact with the air which surrounds the shell and has been heated by it. Because of this temporarily extended combustion-process, the maximum combustion pressure is low and the transformation of chemical energy into heat, even at high engine-speed, is complete and efficient.

A four-cylinder 5⅛ x 7½-in. engine of this type develops 70 hp. at a speed of 1250 to 1300 r.p.m. The compression ratio is about 14.9:1; the mean effective pressure, 72 to 85 lb. per sq. in.; the compression pressure, 441 lb. per sq. in., and the combustion pressure, 682 lb. per sq. in.

Recently the same company has developed a new design having the same number and bore of cylinders but with 7⅛-in. stroke and a compression ratio of 13.8:1. This engine develops 80 hp. at its normal speed of 1500 r.p.m., and weighs between 12 and 15 lb. per hp. The

[18] See *Aircraft Engineering*, (English), May, 1929, p. 82.

[14] See N.A.C.A. Technical Note No. 344, June, 1930.

[15] See N.A.C.A. Technical Report No. 373 (to be published).

[13] See N.A.C.A. Technical Memoranda Nos. 329, 330 and 331, 1925.

[19] See N.A.C.A. Technical Note No. 329, December, 1929.

[20] See N.A.C.A. Technical Memorandum No. 312, 1924.

[21] See N.A.C.A. Technical Note No. 242, July, 1926.

[22] See paper read before the North East Coast Institution of Engineers and Shipbuilders, Dec. 1, 1922.

[23] See paper read before the North East Coast Institution of Engineers and Shipbuilders, Nov. 26, 1920.

[24] See N.A.C.A. Technical Memoranda Nos. 483 and 484, October, 1928.

[25] See N.A.C.A. Technical Memorandum No. 391, 1926.

[26] See Some Characteristics of Nozzles and Sprays for Oil Engines, presented at Third International Power Conference, Berlin, 1930.

[27] Consulting engineer, Detroit.

dimensions of the opening into the combustion-chamber are such as to cause high turbulence and clean combustion without carbon.

Injection is controlled by an REF pump, a section of which is shown in Fig. 6. Superior sealing is a characteristic of this pump because of the long distance between the pressure chamber and the suction chamber and the fact that the compressed fuel surrounds the barrel, thus overcoming the tendency of the pressure inside the barrel to expand it.

The building up of pressure always starts at the same point in the stroke, at the time when the suction valve closes the upper end of the plunger, whereas pumps having their inlets closed by the plunger depend for building up pressure on the distance necessary for sealing the port. This distance increases with the speed of the plunger, the pressure and the wear of the edge of the plunger. The elimination of the need of vacuum to fill the pressure chamber prevents turbulence and makes possible a volumetric efficiency of about 90 per cent regardless of variations in pressure and speed. Any plunger can be put out of operation without stoping the engine. Hand-priming levers facilitate starting the engine by filling the pump and pipe lines with fuel without cranking the engine.

Connection between the throttle lever and plunger is through a universal-joint which prevents side pressure and wear on the plunger. The force required from the governor to control the pump is low.

Observations on Two-Stroke Cycle

F. A. EYSN[28]:—Papers read at this meeting give a very good survey of the present situation in the high-speed Diesel-engine field. Since not much research work has been done on the two-cycle engine, the problems of this type were not much considered, yet I think it is worth while to make a few remarks about this type.

About ten years ago I had the opportunity to work on a two-cycle semi-Diesel engine which ran at what was then the remarkably high speed of 1000 r.p.m. The engine was designed after traditional principles, which govern engineers more than we like to admit, and was therefore very heavy. The scavenging air was compressed in the crankcase, therefore the mean effective pressure was not higher than 45 lb. per sq. in.

Although the engine was a commercial success on account of its simplicity and cheapness, it was a complete failure from an engineering point of view. The scavenging problem was insufficiently solved.

Today we are fairly well able to determine which design would have a chance to make a good two-cycle Diesel engine. The air must be supplied by a separate compressor providing a pressure of about 12 lb. per sq. in. This comparatively high pressure is required because of the shape of the inlet and exhaust ports and the necessity of driving a sufficient amount of cooling and scavenging air through the cylinder. The compressor can be a step piston, a rotary compressor or a turbo compressor. I think that the rotary compressor is the most suitable type for an automotive powerplant. The latest designs show a rather good performance.

Special care has to be devoted to the scavenging process. A cross-section of a cylinder, covered with a glass plate and filled with silk thread, will be very helpful in determining the scavenging-air whirl and thus will furnish valuable information regarding desirable cylinder and piston design.

The nozzle should have a single hole and should be supplied by an individual oil-pump. An air current, created by the piston or perhaps by the inlet ports, should help to distribute the fuel. It may be mentioned that the velocity of this air current is proportional to the engine speed and that it is possible to obtain air velocities up to 300 ft. per sec. at 1200 r.p.m.

The injection-system problems are the same as those of a conventional four-cycle Diesel engine.

From such a machine can be expected a mean effective pressure of about 90 lb. per sq. in. at rated full load, because of the more perfect air supply; an exhaust-gas temperature of 58 deg. fahr. and a weight from 10 to 15 per cent less than that of a gasoline engine of the same power output.

Finally, I desire to give some data obtained on a Junkers engine which was taken from stock. The mean effective pressure at maximum load and 1200 r.p.m. was 114 lb. per sq. in., the excess of air 25 per cent, and the cylinder was filled at the beginning of the compression stroke with 96 per cent of pure air. The exhaust showed a slight tendency to smoke. These are some data worth thinking about.

Improved Instruments Needed

J. L. GOLDTHWAITE[29]:—Diesel-engine development at the present stage is waiting for facts. We cannot make decisions on opinions. Many opinions in regard to Diesel engines which have gained widespread acceptance might be blasted by a little instrumental investigation. For example, it is almost universally accepted that elasticity of the tubes in an injection system allows expansion and causes delayed discharge. Reflection shows that a tube which is worked at 30,000 lb. per sq. in., which is as high a loading as we dare to give it, expands 0.1 per cent, causing an increase in area of 0.2 per cent, which is inconsiderable. The compressibility of the fuel in the line or in a pocket, on the other hand, can be of the order of 1 per cent for each 1000 lb. of pressure. This is not inconsiderable, as compression of oil in a volume of ¼ cu. in. can amount to more than the total charge required for one cylinder of a small Diesel engine.

F. A. EYSN

Instruments must be used to determine many points, of which this is an example. For instance, we built a stroboscope from three 50-watt neon bulbs, at a total cost of $1.50, which uncovered more information on a certain point than six months of theoretical study would give and justified the expense of a more costly stroboscope. We hope to be able later to announce some results of study on pressure conditions in a tube. Those of you who have not tried it will learn a surprising amount by stroboscopic study of the fuel spray.

Mr. Vincent showed a number of indicator diagrams from which he deduced the rate of pressure rise. This

[28] Engineer, development department, Toledo Scale Mfg. Co., Toledo, Ohio.

[29] Assistant chief engineer, Allison Engineering Co., Indianapolis.

he could do because he had taken all the diagrams himself. Whatever errors they might contain, they were comparable. There has been too much comparison of indicator cards taken by different men, and this cannot be done fairly at the present stage of instrumentation because diagrams may be seriously wrong. We need better indicators, as has been pointed out already, and instruments of many other kinds. Above all, we must divide our information into three classes, one consisting of the things we actually know, another of the things of which we know we are ignorant and a much larger class occupying the gap between these two, representing the things of which we are uncertain.

CHAIRMAN W. F. JOACHIM[30]:—There is much truth in these remarks. Methods are lacking for indicating actual fuel pressures and rates of pressure rise in engines running at speeds of 2000 to 3000 r.p.m. As a matter of fact, it is equally difficult to get the pressure rise accurately in a 1000-r.p.m. engine.

Fuel to Which Engines Must Be Adapted

W. H. BUTLER[31]:—Mr. Vincent brought out one of the most important points that I have ever heard discussed in regard to Diesel engines when he showed graphically the design of the fuel cams and how they control the combustion. Most engineers fail to realize the importance of petroleum problems in their relation to oil-engine fuel.

The author of one paper which described a new injection system was asked what type of fuel had been used in the tests reported. He replied that it makes no difference. That is not true. Two classes of fuel are available in this Country, both of them distillates; it is not necessary to use residual oils. Fuels of one of these classes ignite and burn rapidly; but not much of this fuel is available, as it is very satisfactory for cracking and other uses in a refinery. Not much of this will be sold for the operation of high-speed oil engines. Fuels of the other classification have a very high ignition point and burn slowly, thus increasing the ignition lag and causing detonation, after-burning, high exhaust temperatures and smoke.

In the curves of Fig. 4 Mr. Vincent has shown graphically how the cam can be redesigned to cause earlier ignition and to extend the time of burning, thus overcoming some of the difficulties in making use of fuel of the second classification. Fuels of this sort are the ones that will be available, unless customers wish to pay for the additional cost of special products. The oil engine is competing with the gasoline engine on the basis of economy. To do that, it must burn these slow-burning fuels which cause detonation and ignition lag.

Author Replies to Discussion

E. T. VINCENT:—When I was approached to prepare this paper, it was suggested that this subject should be one to inspire discussion. Judging from the results, I must have succeeded in this object at least.

It was stated that 15 years have been needed to increase the speed of the oil engine by 1000 r.p.m. The demand for a high-speed oil engine appeared in 1916-1917, and the speeds have been increased in only 13 years from 400 r.p.m. to the 3000 r.p.m. at which the A.E.C. oil engine runs. Turning to the gas engine for comparison, this type of engine was well established by 1870, as many years of experimenting was required before the automobile engine reached 3000 r.p.m. The reason for the lag in the development of both types was lack of demand.

Exception has been taken to my statements regarding the size of nozzles that have been experimented with, and several references are given to experiments in which small holes have been used. Three of these references had not been published at the time the paper was written, and one has not been published yet, to the best of my knowledge. I have again checked up Mr. Rothrock's reference to the preliminary report of Mr. Gelalles' tests[32]. I fail to find there any data upon holes smaller than 0.014 in., which virtually agrees with the 0.015 in. mentioned in the paper.

Dr. Schweitzer states also that experiments have been made at Pennsylvania State College with 0.007-in. holes, but admits that the results of these tests have never been published. How can tests help practical men unless they are published? So long as these experiments are not available to the industry, they might just as well not have been conducted. He also states that the major characteristics of the sprays from small holes, such as the cone angle and penetration, do not differ from those of large holes. This does not agree with engine results nor with N. A. C. A. tests[33]. Changes in size of nozzle made a variation of 50 per cent in the penetration in these tests. This difference between the results of the various experiments and engine tests was the chief point that I was trying to bring out.

If I have misunderstood Dr. Schweitzer's statements regarding combustion, I am sorry, but the figures I quoted were from his paper[34]. He gives a diagram showing the boundary of completed combustion reaching 13 in. from the nozzle. In the text he states that "some particles burn before they get very far." The diagram shows complete combustion of the lighter particles of spray within 5 in. from the nozzle. Since a travel of 1 in. seems like a large percentage of 5 in., almost instantaneous ignition must be assumed.

Best To Keep Fuel Away from Metal

Contact wtih the surface of any metal, no matter what is its temperature, must slow up combustion. This conclusion is supported by all the experimental work I have conducted during the last 20 years upon engines of many types, including low and high-speed marine engines, medium-speed light-weight engines and high-speed ultra-light engines and also by the low ratings given to all engines having precombustion-chambers and allied construction in which contact does occur. Contact must increase the temperature of the parts, and continuous high output is not possible. Contact of fuel with the metal walls of a direct-injection engine results in a black ex-

E. T. VINCENT

[30] M.S.A.E.—Senior mechanical engineer, Westinghouse Electric & Mfg. Co., South Philadelphia.

[31] Standard Oil Co. of New Jersey, Elizabeth, N. J.

[32] See *Transactions of the American Society of Mechanical Engineers*, OGP-52-5, May-August, 1930, vol. 52, No. 20.

[33] See N.A.C.A. Technical Report No. 356, 1930.

[34] See *Transactions of the American Society of Mechanical Engineers*, OGP-52-15, September-December, 1930, and Fig. 11.

haust. If contact of this sort occurs in the Packard engine, that is one of the causes of the trail of smoke for which this engine has been famed. However, recent reports indicate that the amount of smoke from this engine has been reduced.

This paper is intended to discuss only automotive engines. Specific power is the primary consideration of such engines, and the reduced ratings that result from spray impingement cannot long be tolerated. If competition with gasoline engines is to be at all serious, experimenters must find ways and means of spraying efficiently within small spaces without impingement.

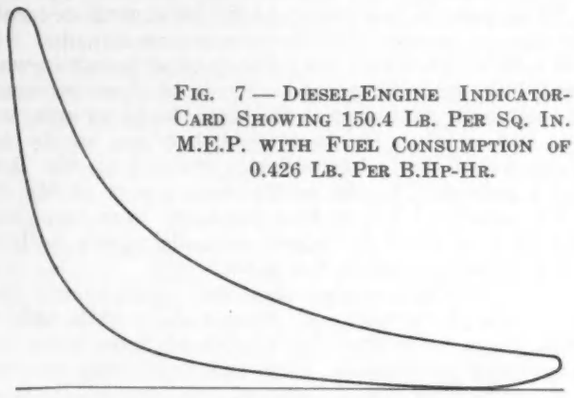


FIG. 7 — DIESEL-ENGINE INDICATOR-CARD SHOWING 150.4 LB. PER SQ. IN. M.E.P. WITH FUEL CONSUMPTION OF 0.426 LB. PER B.HP-HR.

Results such as those shown in Fig 7 could not be secured if the fuel made any contact with the metal surfaces of the combustion-chamber, as was amply demonstrated in experiments upon the engine from which this card was secured. The diagram was taken with a Dalby-Watson optical indicator, calibrated before and after the test. The maximum pressure is only 640 lb. per sq. in., and the fuel consumption 0.426 lb. per b.hp-hr. The brake and indicated mean effective pressures respectively were 126 and 150.4 lb. per sq. in., mechanical efficiency being 83.8 per cent, the engine speed was 286 r.p.m., and the engine was developing 286 b.hp. Tests were continued on this engine for about 8 hr. per day to a total of about 600 hr., maintaining the same mean progress, so this does not represent a temporary peak load.

Figures given in Table 2 show results that can be obtained from a direct-injection system in which oil does not come in contact with the metal. The tests recorded were conducted by Dr. Mellonby, of the Royal Technical College, Glasgow, Scotland, upon a Beardmore engine of light weight.

The maximum pressure in the cylinder was increased to 800 lb. per sq. in. in each case. These tests were not snap readings, and no allowance was made for any exceptional friction of the engine, which was a single-cylinder experimental unit.

Rotary Turbulence and Centrifugal Sprays

I did not claim in my paper that rotary turbulence produces no good results; I was trying to bring out that it is not necessary and is of value only when associated with injection systems such as that used by Ricardo. If a number of small holes are required in the nozzle, little advantage is to be had from rotary turbulence.

Regarding Mr. Rothrock's reference to the results of J. A. Spanogle and H. H. Foster[35], referred to as using large holes in a nozzle containing nine holes, seven of the nine holes were 0.010 in. or smaller in diameter, the remaining two being 0.018 in. The two large holes were necessary because of the shape of the combustion-chamber. One or two large holes are customary in chambers of this particular shape, which was borrowed from the old Lincolnshire engines. However, such shapes are of only limited application, and penetration to a distance of 4 in. only was mentioned as possible with them.

The essential facts regarding centrifugal sprays are well known, the writer's experiments along these lines in 1916 and 1917 giving the same results as those outlined by Mr. Rothrock, but it is not true that such sprays have not been given a fair chance. In my own experiments, at least 100 combinations of elements such as cone angles and area and number of grooves were tried in conjunction with various fuel pressures. In no case did the results approach the performance of the plain-hole nozzle. In spite of this experience, I believe that a spray of this type will eventually come into its own.

Actual engine tests indicate that ignition lag is about one-half as much as the figure recorded by Mr. Rothrock. The time interval from the first appearance of the spray at the exit of the nozzle until the first rise in temperature due to combustion was recorded as approximately 15 deg. crank travel at 1200 r.p.m., or 0.002 sec.

TABLE 2—RESULTS OF TESTS ON A BEARDMORE EXPERIMENTAL ENGINE

Test No.	1	2	3	4
Duration, min.	60	60	60	10
Engine Speed, r.p.m.	1,008.7	1,120	803.5	1,008
Brake Horsepower	83.2	67.7	42.5	95.6
B.M.E.P., lb. per sq. in.	103.0	74.6	65.4	117.0
Fuel Consumption, lb. per b.hp-hr.	0.354	0.311	0.319	....

Mr. von Dorrer's description of the Oberhaensli engine and the REF fuel-pump is very interesting. I agree with Mr. Eysn that the two-cycle Diesel will eventually appear; some excellent results have already been achieved with it.

Mr. Goldthwaite's appeal for more instruments is worthy of support. The stroboscope or some similar instrument is a great aid in studying injection problems; I made extensive use of one while developing the Beardmore engine. Several indicators are available that give consistent results while used by various operators. I have found the R.A.E. electric instrument very satisfactory as a workshop tool.

I appreciate Mr. Butler's discussion of the oil question. Diesel engines can be made that will run satisfactorily on any of the present Diesel-engine oils; whether or not residual oil will ever be used is another question. All Diesel-engine builders should revise their systems until ordinary Diesel fuel can be burned satisfactorily. This will involve scrapping many pretty patent drawings and much sales material about the peculiar advantages attached to the various systems and coming down to a simple and cheap injection system which will operate satisfactorily on ordinary fuels. One advantage of the ordinary fuel is that its lubricating properties greatly increase the life of the pump parts.

Undoubtedly the chemist can improve heavy fuels greatly, but the engine needs so much development first that special fuels are not an urgent necessity.

[35] See N.A.C.A. Technical Note No. 344, June, 1930.

Magnesium
Industry's Lightest Structural Metal

By John A. Gann[1]

AFTER reviewing briefly the history of the aluminum and magnesium industries, the author describes foundry practice in the production of magnesium and magnesium-alloy castings, their heat-treatment and the effect of various fabrication processes on the microstructure and physical properties. The general classes of commercial magnesium-base alloys now in use in this Country are discussed at some length with particular reference to the combination of extreme lightness with good physical and mechanical properties that is obtained.

Applications of magnesium alloys in the aircraft and automobile industries are outlined in a section of the paper. Many of these are illustrated.

In conclusion the author states that the importance of magnesium as a structural metal is now being recognized, especially as the factors that have retarded its development and restricted its use are overcome.

THE light metals have definitely established themselves in our industrial life. This is shown not only by the increasingly large tonnage annually consumed but also by the rapid expansion of the fields in which they are being successfully used. The term "light metals" has been defined[2] as those metallic elements with a specific gravity under 3.8. This definition may sound rather arbitrary, but closer inspection indicates that it is entirely rational. The periodic-table classification of elements concentrates these light metals together, as indicated in Table 1.

These light metals are likewise brought together in the electrochemical series which shows them to be electropositive in relation to the heavy metals. The nature of their occurrence in the earth's crust furthermore differentiates them from the heavy metals. The light metals are found only as stable oxides and salts which are reduced to the metallic state by the expenditure of considerable energy. The heavy metals, on the other hand, occur either in the native state or in the form of readily reducible ores. Table 2 lists the commercial uses of most of the light metals which are governed by their chemical properties to a much greater extent than is the case with the heavier metals. Their outstanding characteristic is their great affinity for oxygen, and advantage is taken of this in many types of chemical reactions, in pyrotechnics and in the deoxidation of the heavier metals. Many of these light metals are successfully used as minor alloying ingredients, but only three members—aluminum, magnesium and beryllium—are sufficiently stable to be considered as structural materials.

TABLE 1—CLASSIFICATION OF LIGHT METALS

Group	Type of Metal	Metals in Group
1	Alkali	Lithium, Sodium, Potassium, Rubidium and Caesium
2	Alkaline Earth	Calcium, Strontium and Barium
3	Related Metal Earth	Magnesium and Beryllium Aluminum

[1] Metallurgist, The Dow Chemical Co., Midland, Mich.

[2] See Chemische Technologie der Leichtmetalle, by F. Regelsberger, p. 2 (1926).

TABLE 2—USES OF LIGHT METALS

Metal	Pyrotechnics	Chemical	Deoxidizer	Alloying Ingredient	Structural Material
Lithium, Sodium, Potassium	.....	Synthesis, Reduction	.....	Modification of aluminum-silicon alloys	.....
Calcium, Strontium, Barium	.....	Synthesis, Reduction	Calcium-Silicon alloys in steel	Lead alloys	.....
Beryllium	.....	.....	.....	Copper-beryllium, Nickel-beryllium, Aluminum-beryllium	X-ray windows and targets. Electrodes in Neon signs
Magnsium	Flashlights, Signals	Grignard reaction	Nickel alloys, Copper alloys	Aluminum alloys, Zinc-base die-castings	Castings, Wrought alloys
Aluminum	Sparklers, Signals	Goldschmidt thermit process	Steel	Aluminum-bronze	Castings, Wrought alloys, Aluminum paint

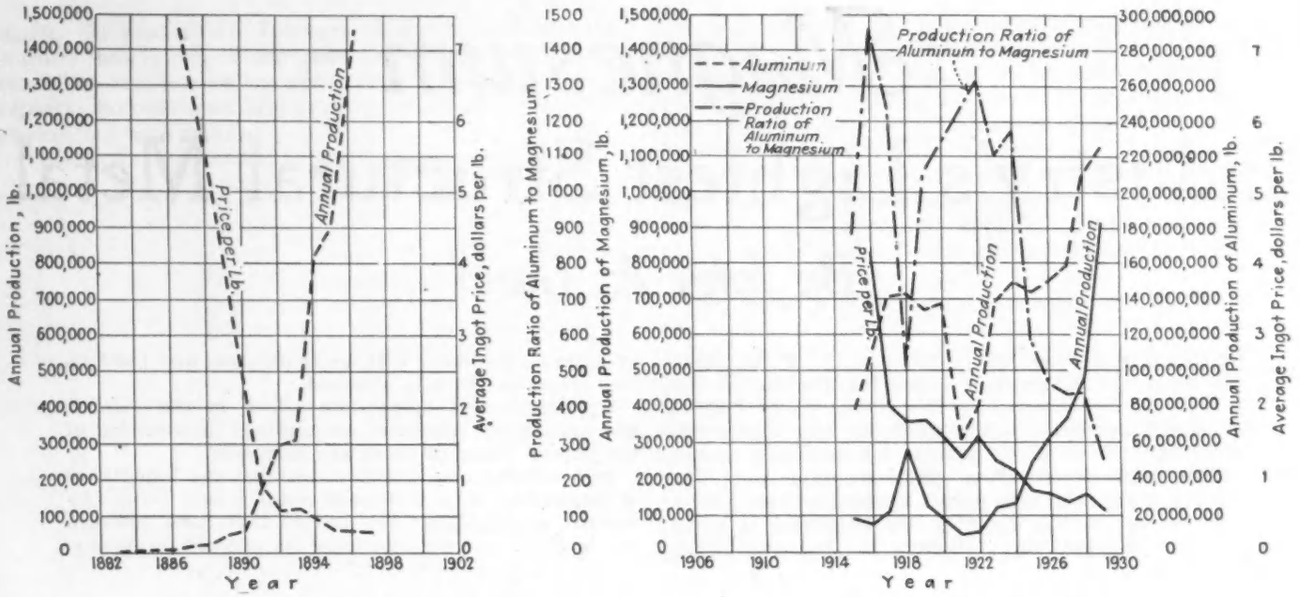


FIG. 1—STATISTICS OF MAGNESIUM AND ALUMINUM PRODUCTION IN THE UNITED STATES

History

The light and heavy metals are again differentiated when viewed from the standpoint of their historical development. Many of our commercial heavy metals have been known and used for thousands of years, while the age of light metals covers but a single century and their large-scale use, a much shorter time. An interesting fact is that the first production of aluminum, magnesium and beryllium occurred at approximately the same time, 1825-1830. Aluminum was the first of these three metals to be used commercially; magnesium followed some years later, while a beryllium industry scarcely exists, since production does not exceed a few pounds daily, valued at from $100 to $200 per lb., and the most optimistic figures predict an ultimate cost of at least from $5 to $10 per lb.

Some of the more important events in the development of the aluminum and magnesium industries are given in Table 3, and a more detailed study of their growth in the United States is given in Fig. 1, which has been compiled from the annual reports of the Bureau of Mines[3]. The similarity in the expansion of these two domestic industries is very strikingly shown, both in regard to the tonnage produced and the reduction in cost of the metal. The relative growth of the magnesium industry in the last few years, however, has been much greater than that of the aluminum industry, as indicated by the curve in the upper right portion of Fig. 1. In 1922, 1300 lb. of aluminum was made for each pound of magnesium, while in 1929 only 250 lb. of aluminum was made for each pound of magnesium.

The cost ratios of aluminum and magnesium are likewise enlightening. When the annual production of aluminum amounted to 1,000,000 lb. the average price was 33 cents per lb. A tenfold increase in the aluminum output decreased the price to 23 cents per lb., or a 30 per cent reduction. In 1929 the magnesium

[3] See Mineral Resources of the United States, 1915-1929.

TABLE 3—HISTORICAL DEVELOPMENT OF ALUMINUM AND MAGNESIUM INDUSTRIES

Aluminum Industry			Magnesium Industry
	1800		
Davy unsuccessfully attempted to electrolyze aluminum oxide and potassium hydroxide	1807	1808	Davy made a magnesium amalgam
Oersted reduced aluminum chloride with potassium amalgam	1825		
Wohler reduced aluminum chloride with potassium	1827	1830	Bussy reduced magnesium chloride with potassium
Bunsen and Deville electrolyzed aluminum chloride and sodium chloride	1854	1852	Bunsen electrolyzed magnesium chloride
Deville reduced aluminum chloride with sodium (commercial process)	1854		
Aluminum bars were publicly displayed at Paris	1855		
		1863	Deville and Caron reduced magnesium chloride with sodium (commercial process)
Hall electrolyzed aluminum oxide in cryolite	1886		
Commercial production began in United States			
		1909	Castings and fabricated parts were publicly displayed in Germany
		1915	Commercial production began in United States
	1925		

consumption was almost 1,000,000 lb. at an average price of 57 cents per lb. A corresponding percentage drop in price by the time production has increased tenfold would mean 40-cent magnesium, and 35-cent magnesium would be directly comparable with 23-cent aluminum, on a volume-for-volume basis. In spite of the 1930 depression, with its decreased output, improvements in process and plant-operation efficiency permitted a large price-reduction near the beginning and another similar reduction at the close of that year. As a result, the average price for ingot magnesium during 1930 dropped to approximately 50 cents per lb. and will be very appreciably lower this coming year. This present trend of progress indicates that the attainment, if not betterment, of the above goal may soon be realized. Magnesium castings and fabricated parts are even now being quoted at prices that are strictly competitive with heat-treated aluminum-alloy aircraft-castings and wrought high-strength aluminum-alloy parts.

Magnesium metal is produced electrolytically from a fused magnesium chloride - sodium chloride cell bath. The metal formed is lighter than the bath and, therefore, rises and floats on its surface but does not burn because of the protecting action of a thin film of the molten salt. On the other hand, the sludge that forms in the normal operation of the cell is heavy and immediately sinks. The sludge is largely due to the small percentage of magnesium oxide present in the cell feed. This automatic separation of metal and sludge; the high purity of the cell feed, less than 0.01 per cent of heavy - metal impurities capable of affecting the quality of the metal; the freedom from contamination due to chemical attack of the magnesium on the cell parts and, finally, the washing and purifying action of the cell bath itself all combine to yield a metal of such purity that subsequent refining is unnecessary. The average analysis of this magnesium direct from the cells reveals a purity of 99.90 per cent, a figure that at times rises to 99.95 per cent. The minute traces of other elements present consist of silicon, iron, aluminum and manganese.

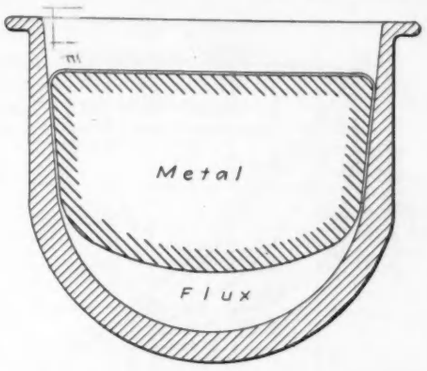


FIG. 2—FOUNDRY POT FOR MAGNESIUM

The Flux Surrounds the Molten Metal, Protects It from Surface Oxidation as Well as from Possible Deleterious Action of Furnace Gases on Overheating or When the Metal Remains Molten for a Long Time, and Purifies It from Non-Metallic Contaminations by a Washing Rather than a Solvent Action

FIG. 3—LADLE USED TO TRANSFER MOLTEN MAGNESIUM FROM THE FOUNDRY POT TO THE MOLDS

These Ladles Are Equipped with a Parting Sweep That Cuts the Protective Flux-Film in the Pot, a Retaining Shield To Hold Back the Surface-Oxide Film That Forms on the Metal in the Ladle and an Under-Feed Pouring Spout so That Only Clean Metal Enters the Mold

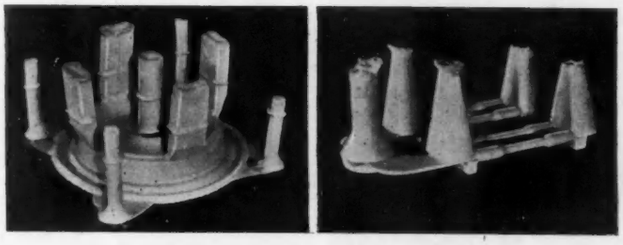


FIG. 4—EXAMPLES OF GATING METHODS FOR MAGNESIUM CASTINGS

In Making the Airplane-Wheel Casting Shown at the Left, Long Wedge-Gates Supplement the Action of Perforated Skim Gates at the Base of the Sprue To Secure a Uniform Feed of Metal Which Is Free from Turbulence and Mechanically Occluded Gas That May Have Been Entrapped in the Sprue. Test-Bar Castings of the Type Shown at the Right Couple Ease of Molding with the Production of Sound Castings

The successful operation of an electrolytic cell using a magnesium chloride-sodium chloride cell bath gave the clue to our present foundry melting-practice. A flux similar in composition to the cell bath performs a multitude of duties. It completely surrounds the molten metal in the foundry pot (Fig. 2), thus protecting it from surface oxidation as well as from possible deleterious action of furnace gases when the metal is overheated or held molten for long periods. It purifies the metal from non-metallic contaminations by a washing rather than a solvent action. This process is so complete that foundry, fabrication and machine-shop scrap can be successfully treated and the resulting melt cannot be distinguished from virgin metal. It likewise permits a continuous melting and casting process. More metal can be added from time to time to a partially empty pot, complete emptying and cleaning being necessary only when the flux is so dirty that it no longer functions properly. The distinctive feature in magnesium foundry-practice is the relatively large proportion of flux used. This generally varies from 30 to 40 per cent of the weight of the full charge of metal. Melting equipment with capacities up to 1000 lb. are in successful operation.

The metal is transferred to molds by ladles of the type shown in Fig. 3, which are equipped with parting sweeps, retaining shields and under-feed spouts. After parting the protective flux-film with the sweep, the ladle is filled with clean metal. Surface-oxide films that may form on the metal in the ladle are held back by the retaining shield and only clean metal enters the mold through the under-feed pouring spout. The low surface-tension of the flux is usually sufficient to cause the protective film to reform after it has been broken as described above, and if not, the reforming can be as-

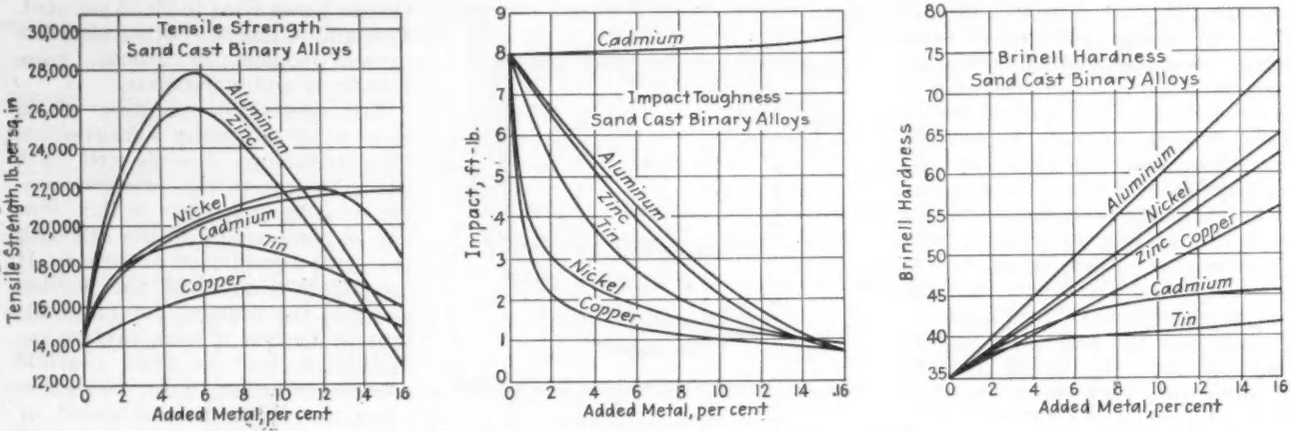


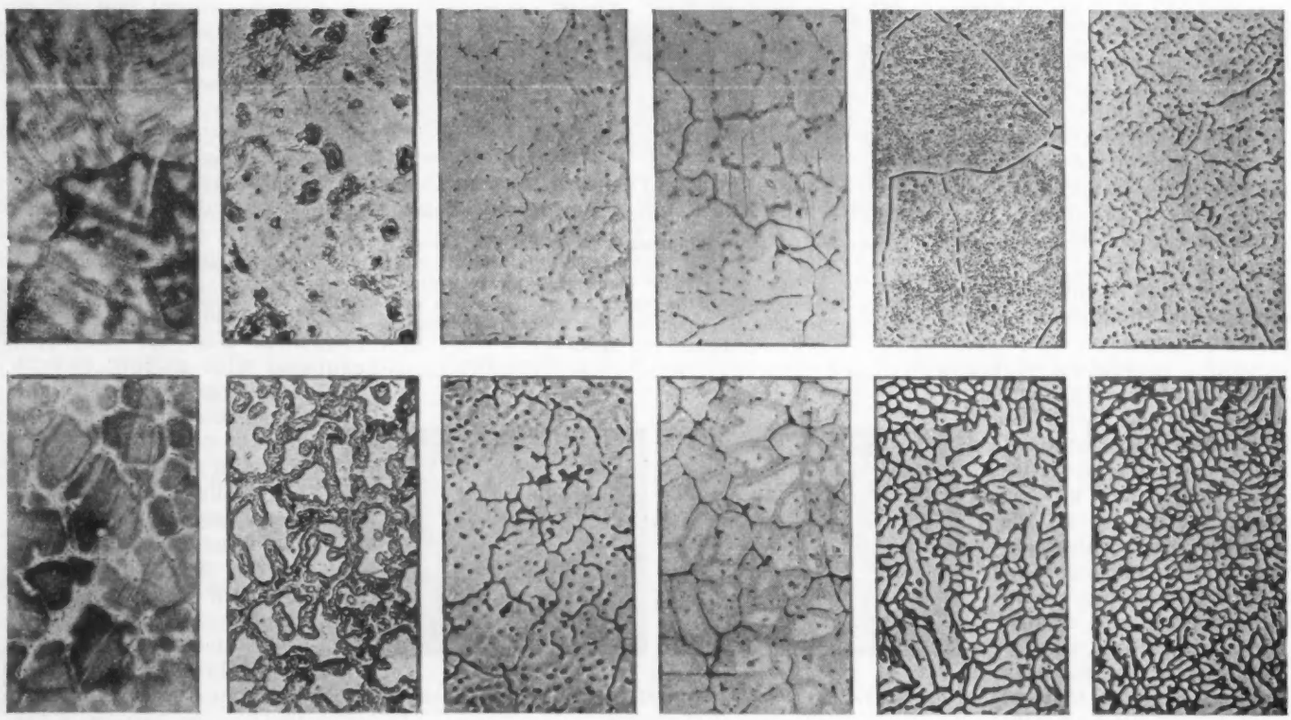
FIG. 5—PROPERTIES OF CAST BINARY MAGNESIUM ALLOYS

sisted by stroking the surface of the pot with the under side of the ladle. German practice specifies a thick pasty flux that forms a semi-solid crust over the metal. Such a procedure may be advantageous in small work where the casting is poured directly from the melting crucible. The American flux is much better adapted to large-scale operations and is particularly fitted for the purification of metal scrap.

In the casting of magnesium, special attention must be given to gates and risers. A perforated skim-gate at the base of each sprue helps to give the casting a uniform feed of metal, free from turbulence and mechanically occluded gas that may have been entrapped in the sprue. The use of long wedge gates, as shown in the left view of Fig. 4, supplements the action of the skim-gate. The extreme lightness of the metal calls for abundant risers to counteract shrinkage and internal porosity. Test specimens, of the type shown at the right, couple ease of molding with sound castings.

Heat-Treatment

Most of the common metals alloy readily with magnesium. Notable exceptions occur in the case of manganese, which forms stable alloys only up to approximately 2 per cent, while iron, chromium, vanadium and



Cadmium	Aluminum	Zinc	Tin	Copper	Nickel
4 Per Cent	4 Per Cent	4 Per Cent	1 Per Cent	1 Per Cent	1 Per Cent
12 Per Cent	12 Per Cent	8 Per Cent	8 Per Cent	8 Per Cent	8 Per Cent

FIG. 6—MICROSTRUCTURAL CHANGES IN CAST MAGNESIUM BINARY ALLOYS WITH INCREASING PERCENTAGE OF ADDED METAL

The Magnification Is 200 Diameters, Reduced by Reproduction to 60 Diameters. All of the Specimens Were Etched with 2-Per Cent Nitric Acid with the Exception of the Cadmium Alloy, Where 2-Per Cent Sulphuric Acid Was Used

TABLE 4—STANDARD DOWMETAL ALLOYS

Alloy	Nominal Composition, Per Cent: Magnesium	Aluminum	Manganese	Cadmium	Copper	Uses
F	95.7	4.0	0.3	..	..	Forging, rolling and extrusion where maximum ductility is required
E	93.7	6.0	0.3	..	..	Castings requiring good strength without heat-treatment Mechanically worked parts requiring both strength and ductility
A	91.8	8.0	0.2	..	..	High strength heat-treated castings Mechanically worked parts requiring maximum strength
T	91.8	2.0	0.2	2.0	4.0	Pistons and other parts requiring maximum thermal properties
M	98.5	..	1.5	..	..	Maximum corrosion resistance Primarily for cast and fabricated parts not subjected to maximum stresses

related metals are practically insoluble in magnesium. The properties of some of the simpler binary alloys in the as-cast condition are shown in Fig. 5. The changes in microstructure with increasing percentage of added metal are shown in Fig. 6. The magnesium-cadmium alloys are very tough but their other properties are low. Alloys forming network eutectics, the magnesium-nickel and magnesium-copper series, have relatively poor mechanical properties unless modified by the addition of toughening ingredients such as aluminum and cadmium, as in Dowmetal *T* (See Table 4). The best combination of properties is obtained in alloys possessing a limited degree of solid solution plus a globular eutectic as present in the magnesium-aluminum and magnesium-zinc series.

The more important types of microstructural changes in magnesium binary alloys as occasioned by heat-treatment are illustrated in Fig. 7. The upper row of micrographs shows the structure of the as-cast alloys. The center row shows the structures of these same alloys heat-treated for 36 hr. at the maximum temperatures possible without appreciable oxidation or melting. The lower row shows the additional changes resulting from a subsequent 24-hr. heating at 150 deg.

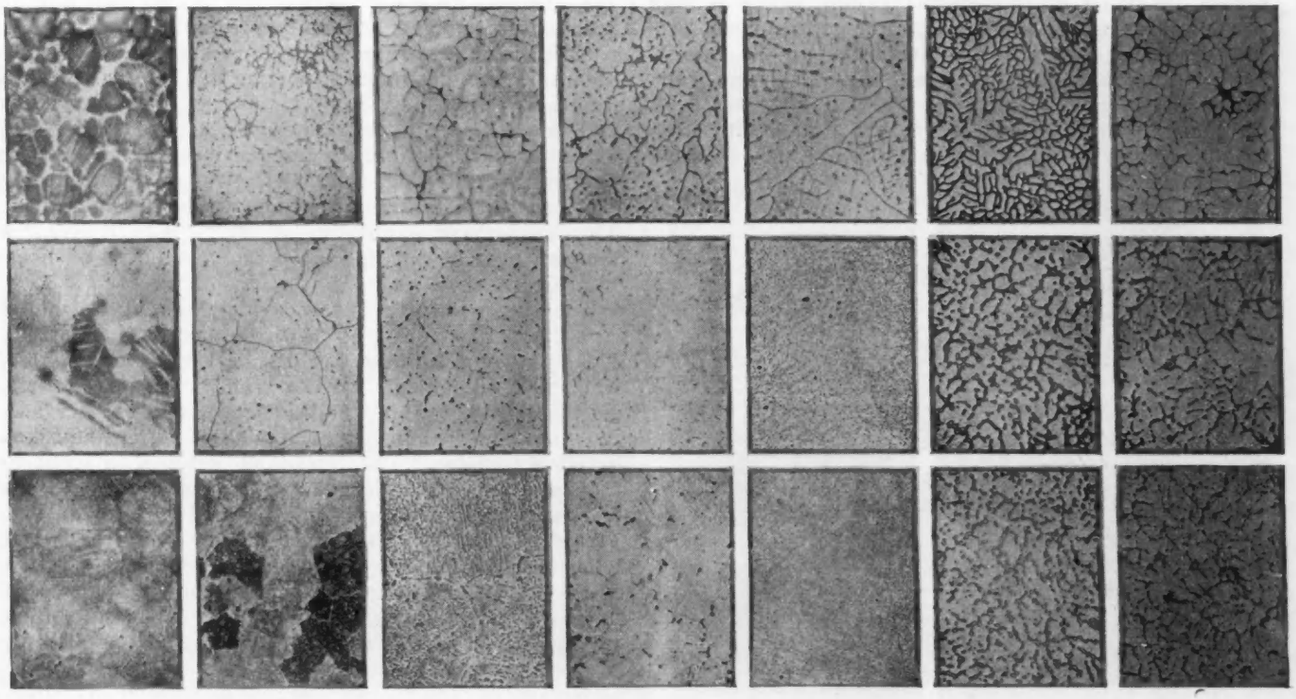


FIG. 7—MICROSTRUCTURAL CHANGES IN MAGNESIUM BINARY ALLOYS PRODUCED BY HEAT-TREATMENT

Each Vertical Row of Micrographs Represents One Alloy. The Magnification Is 200 Diameters, Reduced by Reproduction to 65 Diameters. From Left to Right the Alloying Elements with the Percentages Used and the Etchants Are Cadmium, 12 Per Cent, 2-Per Cent Sulphuric Acid; Aluminum, 8 Per Cent, 2-Per Cent Oxalic Acid; Tin, 8 Per Cent, 2-Per Cent Nitric Acid; Zinc, 8 Per Cent, 2-Per Cent Nitric Acid; Manganese, 1 Per Cent, 2-Per Cent Oxalic Acid; Copper, 8 Per Cent, 2-Per Cent Nitric Acid; and Nickel, 4 Per Cent, 2-Per Cent Nitric Acid. The Specimens in the Top Row Are as Cast and Those in the Center Row Have Been Given a High-Temperature Heat-Treatment for Three Periods of 12 Hr. at Each of the Temperatures Given: Cadmium, 450, 460 and 470 Deg. Cent. (842, 860 and 878 Deg. Fahr.); Aluminum, 390, 400 and 410 Deg. Cent. (734, 752 and 770 Deg. Fahr.); Tin, 450, 460 and 470 Deg. Cent. (842, 860 and 878 Deg. Fahr.); Zinc, 300, 310 and 320 Deg. Cent. (572, 590 and 608 Deg. Fahr.); Manganese, 500, 510 and 520 Deg. Cent. (932, 950 and 968 Deg. Fahr.); Copper, 420, 430 and 440 Deg. Cent. (788, 806 and 824 Deg. Fahr.); and Nickel, 440, 450 and 460 Deg. Cent. (824, 842 and 860 Deg. Fahr.). The Specimens in the Bottom Row Received an Additional Low-Temperature Heat-Treatment of 24 Hr. at 150 Deg. Cent. (302 Deg. Fahr.)

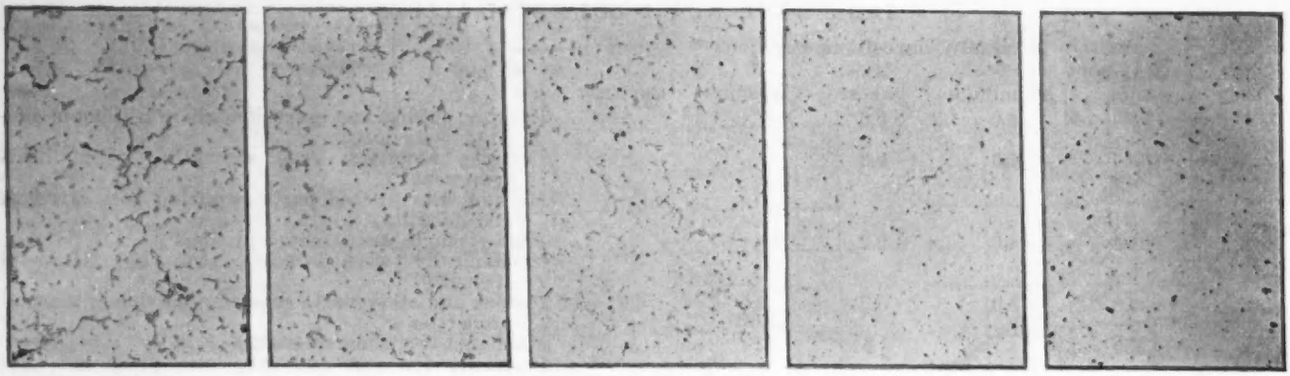


FIG. 9—MICROSTRUCTURAL CHANGES OCCURRING IN CAST DOWMETAL *A* WHEN HEAT-TREATED AT 400 DEG. CENT. (752 DEG. FAHR.)

This Alloy Is Composed of 91.8 Per Cent of Magnesium, 8 Per Cent of Aluminum and 0.2 Per Cent of Manganese. The Magnification Is 200 Diameters, Reduced by Reproduction to 55 Diameters, and the Etchant Used Was 2-Per Cent Oxalic Acid

cent. (302 deg. fahr.). The magnesium-cadmium alloys form a complete series of solid solutions and the only effect of heat-treatment is a reduction in the amount of coring. The high-temperature heating caused a solution heat-treatment in the magnesium-aluminum, magnesium-tin and magnesium-zinc alloys, whereas the subsequent low-temperature heating resulted in a precipitation of part of the dissolved compound. Heating magnesium-manganese alloys at high temperatures eliminates coring and causes some precipitation that formerly was attributed to the rate of precipitation being faster than the quenching rate. Recent work, however, has shown that 500 deg. cent. (932 deg. fahr.) is actually within the precipitation heat-treatment temperature-range and that solution may occur at still higher temperatures. Heating produces little change in the magnesium-copper and magnesium-nickel alloys except a partial spheroidization of the eutectic.

Because of their practical importance, the heat-treatment of the magnesium-aluminum and magnesium-aluminum-manganese alloys has been studied in detail. These two systems may be considered equivalent for the present, inasmuch as the few tenths per cent of manganese present has no appreciable effect on the constitutional diagram or the microstructures. Fig. 8 shows the magnesium-rich portion of the constitutional diagram of the magnesium-aluminum series according to Schmidt and Spitaler[4]. Between 11 and 12 per cent of aluminum is soluble in magnesium at the eutectic temperature 435 deg. cent. (815 deg. fahr.), and only 7 per cent of aluminum is soluble at room temperature. This pronounced change in solubility with decreasing temperatures clearly indicates the feasibility of heat-treating these alloys.

The structural changes occurring in cast Dowmetal *A*, which is composed of 91.8 per cent of magnesium, 8 per cent of aluminum and 0.2 per cent of manganese, when heat-treated at 400 deg. cent. (752 deg. fahr.), are shown in Fig. 9. A light oxalic-acid etch reveals the aluminum-magnesium compound particles unmasked by coring effects. The few dark sections adjacent to the larger masses of compound are precipitated areas formed as the metal cools from the casting temperature. This finely divided precipitate quickly dissolves, while considerable time is required for a complete solution of the larger compound masses. Complete solution in this alloy occurs between 24 and 96 hr. The numerous dark particles, particularly in the 96-hr. heat-treatment, are largely due to etching pits.

Heating at 125 to 300 deg. cent. (257 to 572 deg. fahr.) after the above solution heat-treatment, precipitates small crystals of the compound Al_2Mg_3 from its supersaturated solution. Some interesting stages in this process are shown in Fig. 10. This particular lot of material was solution heat-treated for 16 hr. at 420 deg. cent. (788 deg. fahr.). Although the aluminum is all in solution, complete homogeneity has not been obtained, as is indicated by the nature and location of the areas containing the precipitated compound. These areas are formed first near the grain boundaries where

[4] See *Journal of the Institute of Metals*, vol. 38, p. 195 (1927) and *Zeitschrift für Metallkunde*, vol. 19, p. 452 (1927).

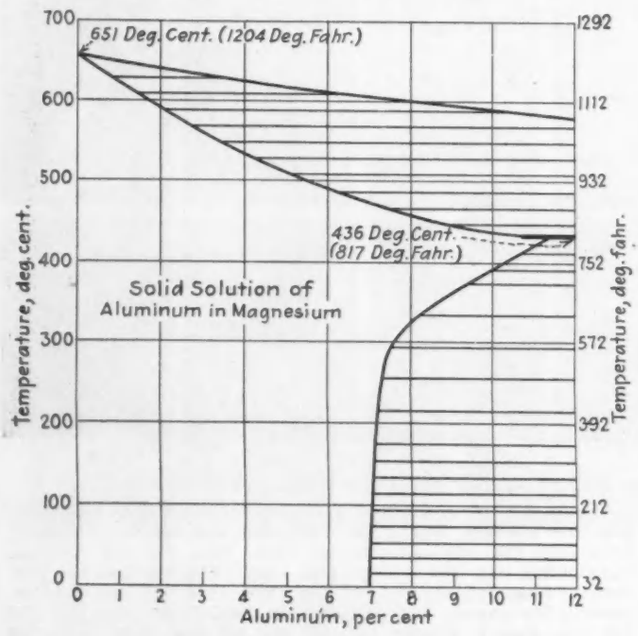


FIG. 8—MAGNESIUM-RICH PORTION OF THE CONSTITUTIONAL DIAGRAM OF THE MAGNESIUM-ALUMINUM SERIES ACCORDING TO SCHMIDT AND SPITALER

TABLE 5—CHANGES IN THE PROPERTIES OF SAND-CAST DOWMETAL *A* AS A RESULT OF HEAT-TREATMENT[a]

	Length of Solution Heat-Treatment at 400 Deg. Cent. (752 Deg. Fahr.), Hr.				
	0	2	4	24	96
Tensile Strength, lb. per sq. in.	26,000	27,000	28,000	35,000	35,000
Yield-Point, lb. per sq. in.	10,000	10,000	10,000	10,000	10,000
Elongation, per cent	5	6	7	11	11
Brinell Hardness	51	51	51	51	51
	Length of Precipitation Heat-Treatment at 175 Deg. Cent. (347 Deg. Fahr.), Hr.				
	0	2	8	24	96
Tensile Strength, lb. per sq. in.	35,000	35,000	36,000	38,000	38,000
Yield-Point, lb. per sq. in.	10,000	10,000	10,000	13,000	16,000
Elongation, per cent	11	11	10	9	4
Brinell Hardness	51	51	51	58	69

[a] Chemical composition:—Magnesium, 91.8 per cent; aluminum, 8 per cent, and manganese, 0.2 per cent.

the degree of supersaturation is greatest and, if the heating continues, they slowly spread throughout the crystals to zones with lower aluminum-content. The structures after 48 and 96 hr. heating definitely reveal the cored dendritic nature of the crystals. At 175 deg. cent. (347 deg. fahr.) the precipitated particles are so small that they are seldom resolved by the microscope, but their rate of growth increases so rapidly with increasing temperature that they are clearly distinguished after a 300-deg. cent. (572-deg. fahr.) heat-treatment.

Table 5 shows that the property changes in Dowmetal *A* due to heat-treatment are in good agreement with observed structural changes. The tensile strength and percentage of elongation increase as the embrittling eutectic is dissolved. Subsequent precipitation causes an additional slight increase in tensile strength but gives a large increase in yield-point and hardness and a decrease in percentage of elongation. The greatest property changes, both during solution and precipitation heat-treatments, occur simultaneously with the greatest microstructural changes. The numerical values for the notched-bar impact-toughness test, as expressed in foot-pounds of energy absorbed in the Dow machine, are approximately equal to the numerical values as given for the percentage of elongation.

Fabrication

Alloys best adapted for fabrication by mechanical-working operations are those of the solid-solution type or those containing relatively small quantities of spheroidized eutectics. The magnesium-aluminum-manganese alloys, such as Dowmetals *A*, *E* and *F*, represent the first type, while Dowmetal *T* is a good example of the latter (See Table 4). Such alloys lend themselves to most hot-working operations, preferably between 200 and 425 deg. cent. (392 and 797 deg. fahr.). A limited amount of cold-working is possible on thoroughly worked and annealed metal, particularly in sheet form. Best results are obtained at moderate working-speeds, as this gives the metal sufficient time to flow into its new shape. Press-forging, for example, is recommended rather than drop-forging, especially in the

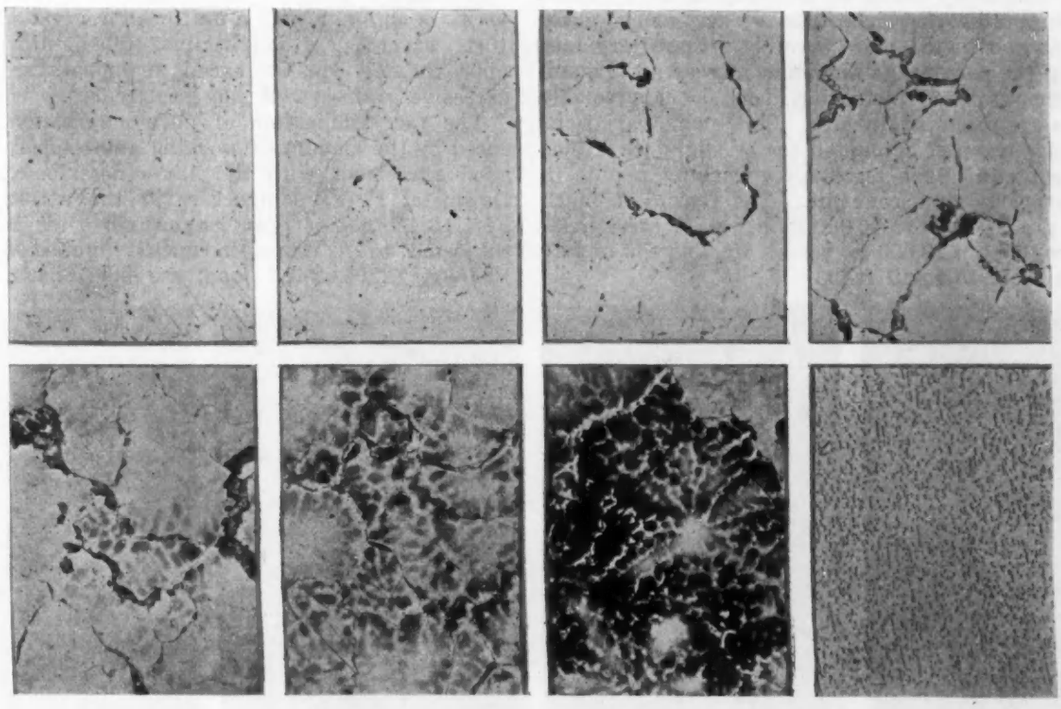
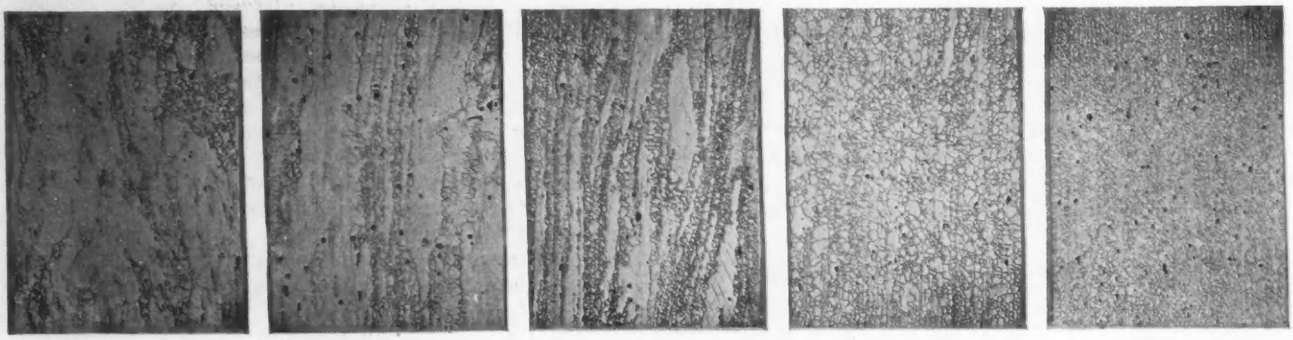


FIG. 10—MICROSTRUCTURAL CHANGES OCCURRING IN THE PRECIPITATION HEAT-TREATMENT OF DOWMETAL *A* AT 175 DEG. CENT. (347 DEG. FAHR.)

Reading from Left to Right, the Top Row Shows a Specimen after a 16-Hr. Solution Heat-Treatment at 420 Deg. Cent. (788 Deg. Fahr.) and Specimens That Were Given a Subsequent Precipitation Heat-Treatment for 2, 8 and 16 Hr. at 175 Deg. Cent. (347 Deg. Fahr.). The Specimens in the Bottom Row Were Heat-Treated for 24, 48 and 96 Hr. and the One at the Right Was Given a 24-Hr. Precipitation Heat-Treatment at 300 Deg. Cent. (572 Deg. Fahr.). All Specimens Were Etched with 2 Per Cent Oxalic Acid. The Magnification Is 100 Diameters, Reduced by Reproduction to 50 Diameters, with the Exception of the Specimen at the Lower Right Where the Magnification of 1000 Diameters Is Reduced by Reproduction to 500



50 Per Cent | 75 Per Cent | 90 Per Cent | 97 Per Cent | 99 Per Cent

FIG. 11—EFFECT OF REDUCTION IN AREA ON THE MICROSTRUCTURE OF EXTRUDED DOWMETAL *F*

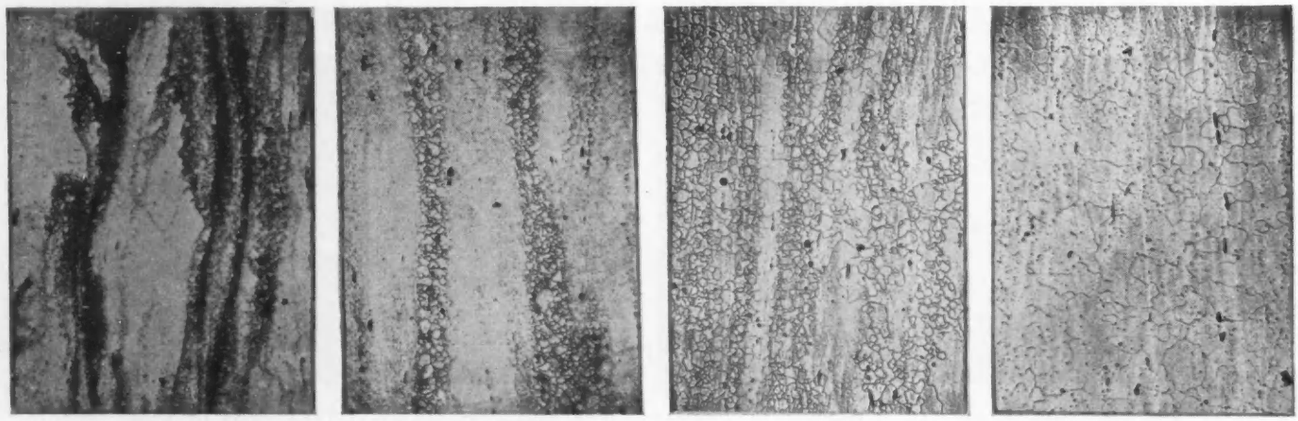
This Alloy Is Composed of 95.7 Per Cent of Magnesium, 4 Per Cent of Aluminum and 0.3 Per Cent of Manganese. The Various Percentage Reductions in Area Indicated under the Different Views Were Obtained in Commercial Extrusions Made at about 375 Deg. Cent. (707 Deg. Fahr.) Starting with 6 and 8-In. Billets. The Magnification Is 100 Diameters, Reduced by Reproduction to 50 Diameters. The Etchant Used Was 3½-Per Cent Nitric Acid, ½-Per Cent Malic Acid and a Trace of Ferric Chloride

higher-percentage aluminum alloys with their lower ductility.

The effect of increased amounts of hot-working as applied to Dowmetal *F*, which is composed of 95.7 per cent of magnesium, 4.0 per cent of aluminum and 0.3 per cent of manganese, is shown in Fig. 11. The various percentage reductions in area were obtained in commercial extrusions made at about 375 deg. cent. (707 deg. fahr.), starting with 6 and 8-in. diameter billets. A 50-per cent reduction in area distorts but does not completely break up the original cast grains. Some recrystallization has taken place along grain boundaries and in the more severely stressed crystals. Increasing the percentage reduction increases the quantity of recrystallized metal but does not appreciably affect the resultant grain size. The small variations in grain size are best accounted for by slight variations in temperatures. Such mechanical working results in marked property improvements. The tensile strength increases from 28,000 to 40,000 lb. per sq. in., the yield-point from 6500 to 28,000 lb. per sq. in., and the impact toughness from 10 to 15 ft-lb.

Fig. 12 shows the effect of extrusion temperature on the structure of Dowmetal *F* after an 83-per cent reduction in area. The dark areas in the 250-deg. cent. (482-deg. fahr.) structure are zones of incipient recrystallization, where the new grains are too small to be resolved. At 300 deg. cent. (572 deg. fahr.) these areas are fully recrystallized, while at 400 deg. cent. (752 deg. fahr.) the less stressed areas are likewise recrystallized, but with very little grain growth. Grain growth has become excessive at 500 deg. cent. (932 deg. fahr.). Greatest uniformity of directional properties is obtained with a uniformly recrystallized structure, nevertheless longitudinal tensile-properties are approximately constant except at temperatures at which excessive grain-growth has occurred.

The recrystallization of pure magnesium, as influenced by the amount of working and temperature, is in good agreement with the above described results on Dowmetal *F*. The structure at the extreme left in Fig. 13 is that of pure magnesium after it has been subjected to a Brinell-hardness impression using a 1000-kg. (2204.62-lb.) load, the field shown being at



250 Deg. Cent. (482 Deg. Fahr.) | 300 Deg. Cent. (572 Deg. Fahr.) | 400 Deg. Cent. (752 Deg. Fahr.) | 500 Deg. Cent. (932 Deg. Fahr.)

FIG. 12—EFFECT OF EXTRUSION TEMPERATURE ON THE MICROSTRUCTURE OF DOWMETAL *F* AFTER A REDUCTION IN AREA OF 83 PER CENT

The Progress in Grain Growth from the Zones of Incipient Recrystallization, Indicated by the Dark Areas in the View at the Left, to the Excessive Grain-Growth in the View at the Right Is Apparent from an Examination of the Micrographs. The Magnification Is 100 Diameters, Reduced by Reproduction to 60 Diameters. The Etchant Used Was a Mixture of 3½-Per Cent Nitric Acid and ½-Per Cent Malic Acid to Which a Trace of Ferric Chloride Was Added

right angles to the surface receiving the load. The left central structure shows this same field after the metal has been heated 16 hr. at 200 deg. cent. (392 deg. fahr.). Recrystallization has occurred chiefly along grain boundaries and in those crystals adjacent to the worked surface, that is, where maximum deformation has occurred. Subsequent heating of this same specimen for 4 hr. at 300 deg. cent. (572 deg. fahr.) caused the recrystallization to spread throughout these crystals and also to advance along grain boundaries into the less stressed sections of metal, as shown in the right central view. Additional heating at 400 deg. cent. (752 deg. fahr.) has resulted in complete recrystallization. As can be seen in the view at the extreme right, the grain size near the surface is about normal for fully worked magnesium, while the coarser structure that is farther away from the surface is typical of partially worked, recrystallized magnesium.

Commercial magnesium alloys can be satisfactorily joined either by acetylene fusion-welding or by pressure methods, such as electric spot or seam welding. Electric-arc methods have not been adapted to these alloys. Acetylene welding requires a suitable flux, but inert atmospheres and other special equipment are not needed. Welding technic differs slightly from that used with steel, chiefly due to the relatively low melting-points of these alloys, but any good welder can make satisfactory magnesium-alloy welds after a few hours' practice. Several commercial aluminum-welding fluxes have been found satisfactory. They are composed essentially of sodium, potassium and lithium chlorides. Magnesium-alloy welding-wire should be of approximately the same composition as the material being welded. Acetylene welds on magnesium-alloy sheet have tensile strength of from 25,000 to 30,000 lb. per sq. in., while the strengths of thicker welded sections average from 20,000 to 25,000 lb. per sq. in.

Satisfactory electric spot-welds have been made on magnesium-alloy sheet up to ¼ in. thick. Higher current-densities are required than in the case of steel spot-welding because of the higher electrical conductivity of the magnesium alloys. The data in Table 6 are typical of the strengths obtained on single spot-welds of Dowmetal *F*.

TABLE 6—DATA ON SINGLE SPOT-WELDS IN DOWMETAL *F*

Thickness of Sheet, In.	Tensile Strength, Lb. per Weld
1/32	500– 600
1/16	900–1,000
1/8	1,600–1,900
1/4	1,900-2,200

Riveted joints on magnesium-alloy sections can be made using rivets of approximately the same composition. Rivets should be driven hot, at a temperature between 300 and 400 deg. cent. (572 and 752 deg. fahr.), preferably by pressure or squeezing rather than by hammer blows. Standard 2*S* or 3*S* aluminum rivets can be used where hot-riveting is not feasible. The design of riveted magnesium-alloy joints, the same as with other metals, is based on the shear strength of the rivet and on the tensile strength and bearing strength of the sheet. The shear strength of magnesium-alloy rivets is approximately one-half the tensile strength of the alloy, while the bearing strength of the magnesium-alloy sheet is approximately 50 per cent greater than its tensile strength.

Ease of machineability is another big asset in all magnesium alloys, and in this respect they have no superior. Both speed and depth of cut can be materially increased over usual shop practice with other metals, while light finish-cuts give a smooth surface that can be held to exact dimensions. Such factors must be taken into consideration in manufacturing operations requiring much machine work, as they often permit articles to be made more cheaply from magnesium than from cheaper but more difficultly machined metals.

Commercial Alloys

Commercial magnesium-base alloys, now in use in this Country, fall into three general classes: (*a*) magnesium-aluminum-manganese alloys, (*b*) magnesium-manganese alloys and (*c*) complex magnesium-copper alloys. The great majority of magnesium castings and fabricated parts are now made from the first type be-

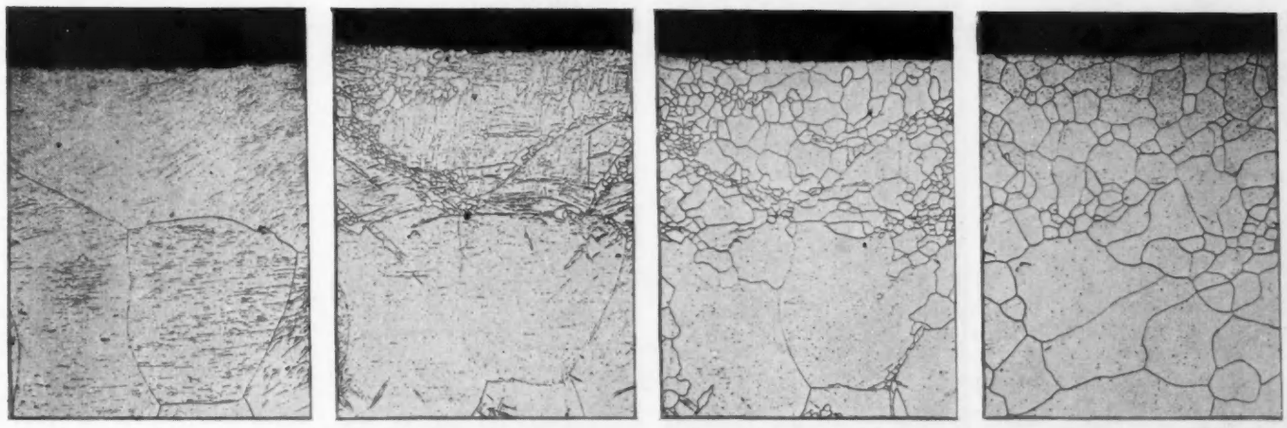


FIG. 13—RECRYSTALLIZATION OF PURE MAGNESIUM

The Micrograph at the Left Shows the Structure after a Brinell Hardness-Test Using a 1000-Kg. (2204.62 Lb.) Load, the Field Shown Being at Right Angles to the Surface Receiving the Load. The Next Micrograph to the Right Shows the Same Field After the Metal Has Been Heated for 16 Hr. at 200 Deg. Cent. (392 Deg. Fahr.). Subsequent Heating of This Specimen for 4 Hr. at 300 Deg. Cent. (572 Deg. Fahr.) Caused an Increase in Recrystallization as Illustrated in the Right Central Micrograph and Additional Heating at 400 Deg. Cent. (752 Deg. Fahr.) Resulted in Complete Recrystallization as Shown at the Extreme Right. The Magnification Is 100 Diameters, Reduced by Reproduction to 60 Diameters

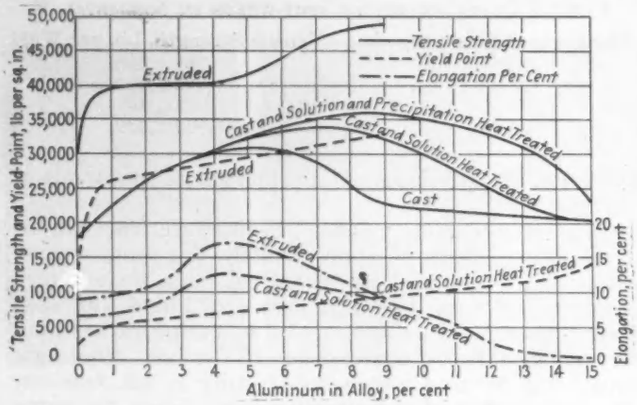
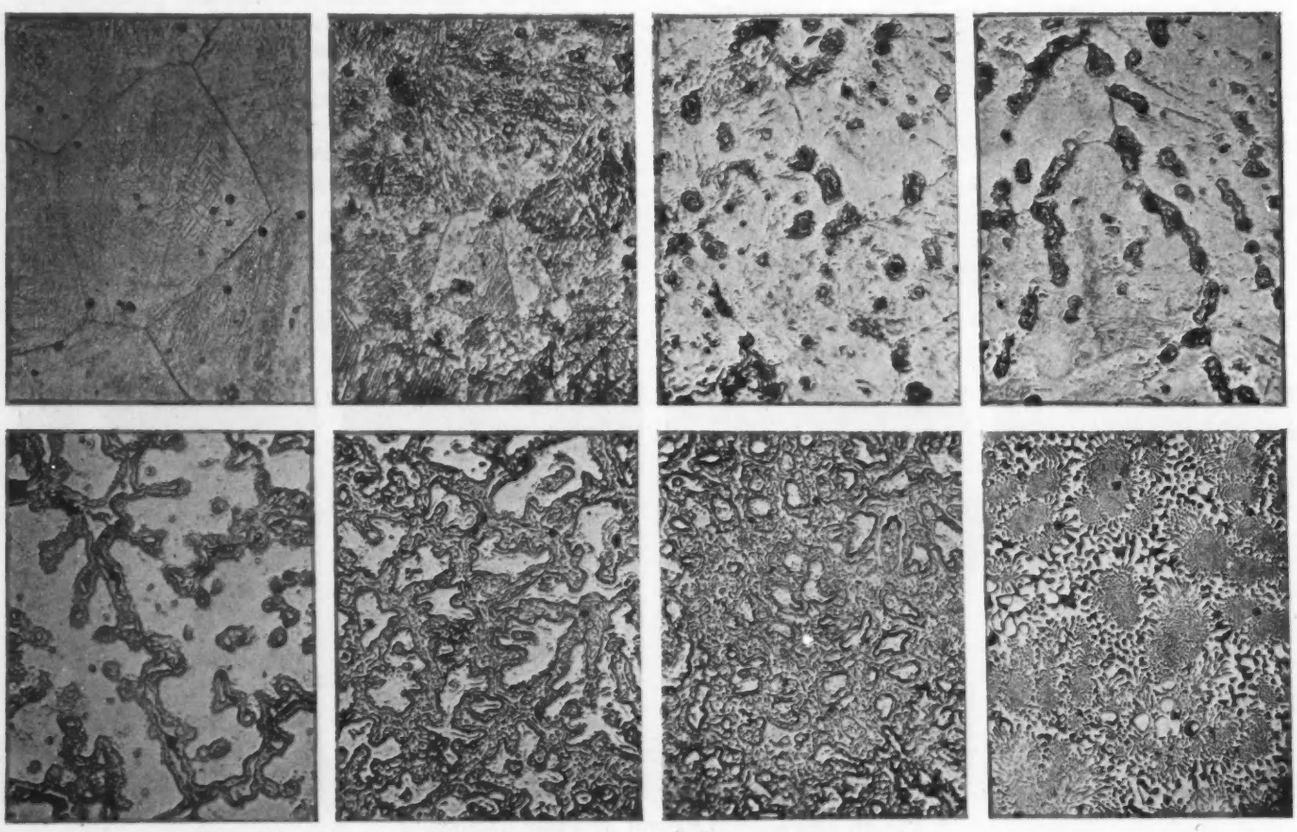


FIG. 14—EFFECT OF COMPOSITION AND TREATMENT ON THE PHYSICAL PROPERTIES OF MAGNESIUM-ALUMINUM-MANGANESE ALLOYS

cause of their superior mechanical properties. Pistons for internal-combustion engines and other parts requiring superior thermal properties constitute an exception and are made from the copper-bearing alloy. The commercialization of the magnesium-manganese alloys is a more recent development. They are of special interest because of their excellent corrosion resistance.

The properties of the magnesium-aluminum-manganese alloys as affected by composition and treatment are shown in Fig. 14. The percentage of manganese in these alloys is not indicated but varies from approximately 0.5 per cent in the 2-per cent aluminum alloy to 0.1 per cent in the 15-per cent aluminum alloy. These quantities of manganese represent the equilibrium percentages that can be normally retained in such alloys, but they are sufficient to raise the yield-point of the worked alloys 6000 to 8000 lb. per sq. in. The curves as drawn start with pure magnesium as the 0-per cent aluminum alloy. In alloys containing more than 4 per cent of aluminum, the impact-toughness curves are approximately parallel to the percentage-of-elongation curves. Hardness values increase slowly but are directly proportional to the percentage of aluminum present. Items of particular interest are

(1) Maximum in the tensile strength of the cast alloy near 6 per cent of aluminum
(2) Maxima in the percentage-of-elongation curves near 4 per cent of aluminum
(3) Rise in the tensile strength of extruded alloys when the aluminum content is increased above 4 per cent
(4) Increase in the tensile strength due to heat-treatment of the cast metal
(5) Maximum in the tensile strength of the cast-solu-



Aluminum in Alloy, Per Cent

0	2	4	6
8	15	20	31

FIG. 15—MICROSTRUCTURES OF CAST MAGNESIUM-ALUMINUM ALLOYS

The Magnification Is 200 Diameters, Reduced by Reproduction to 120 Diameters. The Etchant Was 2-Per Cent Nitric Acid

tion-heat-treated alloys near 8 per cent of aluminum

(6) Increase in the yield-point due to mechanical working

The structures of the as-cast alloys are given in Fig. 15. Fabricated alloys are usually solution heat-treated before working and will, therefore, have structures comparable with those shown in Figs. 11 and 12.

Alloys intended for casting purposes usually contain from 6 to 8 per cent of aluminum plus manganese, although up to 12 per cent of aluminum is permissible where high yield-point and hardness are required rather than maximum tensile-strength plus good elongation and toughness. Such alloys are susceptible to heat-treatment and are generally so used. Compositions with less than 6 per cent of aluminum are not as desirable because of their low yield-point and poorer casting-qualities, such as low fluidity and high solidification-shrinkage. The use of the 6-per cent aluminum-0.2-per cent manganese composition as a casting alloy is increasing, as it possesses a tensile strength of approximately 30,000 lb. per sq. in. without the necessity of time-consuming and expensive heat-treating operations. Alloys with from 4 to 6 per cent of aluminum plus manganese are generally recommended for mechanical-working processes. An increase in aluminum content gives better properties but increases the power consumption and narrows the working-temperature range.

Magnesium-manganese binary alloys have been known for some time but production and fabrication methods, as well as a correct appreciation of their true value, are developments of the last few years. Published literature dealing with this system of alloys is extremely scanty. The work of Schmidt[5], Bakken and Wood[6] and Pearson[7] places the upper limit of true alloyability at about 4 per cent of manganese. Different ideas, however, are expressed relative to the formation of solid solutions, intermetallic compounds and the like. Our own work indicates that, while a 4-per cent manganese alloy can be prepared, much of this manganese is present as a mechanical suspension and soon

[5] See *Zeitschrift für Metallkunde*, vol. 19, p. 452 (1927).
[6] See National Metals Handbook, 1930 edition, p. 742.
[7] See *Industrial and Engineering Chemistry*, vol. 22, p. 367 (1930).

TABLE 7—MECHANICAL PROPERTIES OF SAND-CAST MAGNESIUM ALLOYS,[b] BASED ON STANDARD UNMACHINED 1/2-IN. TEST BARS

Property	Cast and Heat-Treated Dowmetal *M*	Cast Dowmetal *E*	Cast Dowmetal *A*	Cast and Heat-Treated Dowmetal *A*	Cast Dowmetal *T*
Tensile Strength, lb. per sq. in.	18,000–20,000	28,000–31,000	24,000–27,000	31,000–35,000	22,000–25,000
Yield-Point, lb. per sq. in.[c]	5,000– 7,000	7,000– 8,000	8,000–10,000	8,000–10,000	6,000– 7,000
Elongation in 2 In., per cent	3–6	9–12	4–7	9–12	4–7
Compression Strength, lb. per sq. in.	28,000–30,000	40,000–42,000	41,000–44,000	42,000–45,000	38,000–40,000
Shear Strength, lb. per sq. in.	10,000–12,000	13,000–15,000	14,000–16,000	14,000–16,000	13,000–15,000
Brinell Hardness	38–42	46–50	48–52	48–52	43–48
Rockwell *E* Hardness	25–41	50–60	55–62	55–62	43–55
Impact Toughness as Measured on a Dow Machine, ft-lb.	4–6	7–9	3–5	9–12	3–4
Fatigue-Endurance Limit, lb. per sq. in.	3,000– 4,000	8,000– 9,000	8,000–10,000	8,000–10,000	6,000– 7,000

[b] Chemical compositions of the various alloys are given in Table 4.
[c] Yield-point is taken as the load at which the stress-strain curve deviates 0.1 per cent elongation from the modulus line. The modulus of elasticity of magnesium alloys is 6,500,000 lb. per sq. in.

TABLE 8—MECHANICAL PROPERTIES OF FULLY WORKED WROUGHT MAGNESIUM-ALLOYS,[d] BASED ON A 90-PER CENT REDUCTION IN AREA

Property	Dowmetal *M*	Dowmetal *F*	Dowmetal *E*	Dowmetal *A*	Dowmetal *T*
Tensile Strength, lb. per sq. in.	38,000–42,000	37,000–41,000	40,000–44,000	42,000–48,000	38,000–42,000
Yield-Point, lb. per sq. in.[e]	22,000–25,000	26,000–30,000	28,000–32,000	28,000–32,000	27,000–31,000
Elongation in 2 In., per cent	5–8	12–16	10–15	8–12	5–9
Compression Strength, lb. per sq. in.	45,000–50,000	57,000–60,000	58,000–62,000	60,000–65,000	50,000–55,000
Shear Strength, lb. per sq. in.	15,000–17,000	17,000–19,000	17,000–19,000	18,000–20,000	17,000–19,000
Brinell Hardness	38–42	45–50	50–55	54–58	45–50
Rockwell *E* Hardness	25–40	50–60	60–66	65–70	50–60
Impact Toughness as Measured on a Dow Machine, ft-lb.	10–12	14–16	15–18	11–15	6–8
Fatigue-Endurance Limit, lb. per sq. in.	9,000–10,000	12,000–13,000	13,000–15,000	14,000–16,000	13,000–14,000

[d] Chemical compositions of the various alloys are given in Table 4.
[e] Yield-point is taken as the load at which the stress-strain curve deviates 0.1 per cent elongation from the modulus line. The modulus of elasticity of magnesium alloys is 6,500,000 lb. per sq. in.

TABLE 9—PHYSICAL CONSTANTS OF MAGNESIUM ALLOYS[f]

Property	Magnesium	Dowmetal *M*	Dowmetal *F*	Dowmetal *E*	Dowmetal *A*	Dowmetal *T*
Specific Gravity	1.74	1.76	1.76	1.78	1.80	1.82
Weight, lb. per cu. in.	0.063	0.064	0.064	0.064	0.065	0.066
Melting Point, deg. fahr.	1,204	1,200[g]	1,155	1,135	1,120	1,185
Coefficient of Thermal Expansion per Deg. Fahr.	0.000016	0.000016	0.000016	0.000016	0.000016	0.000016
Thermal Conductivity, C.G.S. units	0.38	0.30[g]	0.23	0.20	0.18	0.30

[f] Chemical compositions of the various alloys are given in Table 4.
[g] Approximate.

settles out of the molten alloy to an equilibrium content of approximately 2 per cent. Property improvements are obtained in both cast heat-treated and wrought alloys as the manganese is increased up to about 1.25 per cent. Further additions of manganese produce little or no additional property changes. The properties of cast magnesium-manganese alloys are substantially the same as those of cast magnesium. Precipitation heat-treatment produces marked property changes, particularly in yield-point. Such effects are obtained at temperatures of from 250 to 550 deg. cent. (482 to 1022 deg. fahr.), the maximum improvement occurring at about 350 deg. cent. (662 deg. fahr.). Wrought magnesium-manganese alloys offer more commercial promise than the cast material. Fully worked extruded and forged sections possess properties only slightly inferior to those of the magnesium-aluminum-manganese alloys.

Magnesium alloys are now produced and marketed in this Country under various trade names, such as *AM* alloys, Bohnalite *X* and Dowmetal. Similar compositions developed in Germany are known as Elektron. Domestic alloy-compositions have been selected on the basis of mechanical properties, ease of fabrication and corrosion resistance. They are typified by the series of Dowmetal alloys listed in Tables 4, 7, 8 and 9, which indicate the field of utility of each alloy and give a resumé of their more important properties. Heat-treatment after hot-working operations is not necessary, since rolling, forging, extrusion and the like develop the full strength of the metal. The properties given in Table 8 are for fully worked metal with 90 per cent or more reduction in area. Large forgings that have not been as thoroughly worked have somewhat lower properties. Dowmetal *F* sheet has an ultimate tensile-strength of from 33,000 to 40,000 lb. per sq. in. with a 12 to 16-per cent elongation. Corresponding values for Dowmetal *M* sheet are 30,000 to 35,000 lb. per sq. in. and 4 to 10-per cent elongation.

The superior corrosion-resistance of standard magnesium alloys as compared with their earlier counterparts has been established both in the laboratory and by performance in actual service. Exposure tests covering a period of years have demonstrated that magnesium alloys are now to be classed among the more

TABLE 10—RELATIVE WEIGHTS OF STRUCTURAL METALS

Material	Specific Gravity	Relative Weight	Weight, Lb. per Cu. Ft.
Magnesium Alloys	1.8	1.0	112
Aluminum Alloys	2.8	1.5	175
Cast Iron	7.1	3.9	443
Zinc	7.2	4.0	449
Tin	7.3	4.1	455
Steel	7.9	4.4	493
Brass	8.5	4.7	530
Bronze	8.6	4.8	536
Nickel	8.9	4.9	555
Copper	8.9	4.9	555
Lead	11.3	6.3	705

permanent structural-metals from the standpoint of atmospheric corrosion. Factors contributing to this improvement include (*a*) greater purity of the ingot metal, (*b*) better understanding and control of foundry operations and (*c*) the use of manganese as an ingredient of all alloys. Maximum immunity to salt water is obtained in the magnesium-manganese alloys. Corrosion resistance in this series increases with increasing manganese content up to about 1.25 per cent and then remains approximately constant. A similar relationship between composition and property improvement was pointed out earlier in the paper. Samples of such alloys show but little attack after from 8 to 10 months' alternate immersion in a 3-per cent salt solution. Their corrosion resistance can be partly attributed to a protective film that forms on the surface.

The evaluation of laboratory corrosion data in terms of service performance is recognized as a difficult task. Various magnesium alloys, for example, with corrosion rates in accelerated tests differing by several hundred per cent often show practically the same corrosion resistance in long-time atmospheric tests. These observations are substantiated by commercial work where magnesium-alloy parts have been entirely satisfactory even though used under conditions where excessive corrosion might have been expected. Engine castings, with no protection except a film of oil and grease that developed during normal operation, have been successfully used in amphibian planes.

The absence of intercrystalline corrosion in magnesium alloys has been a big asset in establishing their dependability. Tensile-property determinations on material stored for from 10 to 12 years, as well as on

TABLE 11—RELATIVE PROPERTIES OF VARIOUS STRUCTURAL METALS

Material	Specific Gravity	Young's Modulus of Elasticity, Lb. per Sq. In.	Ultimate Tensile-Strength, Lb. per Sq. In.	Yield-Point, Lb. per Sq. In.	Fatigue-Endurance Limit, Lb. per Sq. In.	Specific Tensile-Strength,[A] Lb. per Sq. In.	Specific Yield-Point,[A] Lb. per Sq. In.	Specific Fatigue-Endurance Limit,[A] Lb. per Sq. In.
Wrought Alloys								
Chromium-Molybdenum Steel	7.9	30,000,000	100,000	70,000	50,000	12,700	8,860	6,330
Chromium-Molybdenum Steel, Heat-Treated	7.9	30,000,000	175,000	140,000	85,000	22,100	17,700	10,800
Mild Carbon Steel	7.9	30,000,000	60,000	33,000	30,000	7,600	4,180	3,800
Duralumin (17*ST*)	2.8	10,000,000	60,000	35,000	15,000	21,400	12,500	5,360
Dowmetal *E*	1.8	6,500,000	40,000	28,000	14,000	22,200	15,500	7,780
Cast Alloys								
Cast Iron	7.1	15,000,000	30,000	.....	12,000	4,220	.....	1,690
Aluminum Alloy No. 12 (S.A.E. No. 30)	2.8	10,000,000	22,000	14,000	8,000	7,860	5,000	2,860
Aluminum Alloy No. 195-4 (S.A.E. No. 38), Heat-Treated	2.8	10,000,000	33,000	16,000	6,000	11,800	5,720	2,140
Dowmetal *A*, Heat-Treated	1.8	6,500,000	33,000	9,000	9,000	18,300	5,000	5,000

[A] The specific tensile-strength, yield-point and fatigue-endurance limit are equal to the actual tensile-strength, yield-point and fatigue-endurance limit divided by the specific gravity.

alloys subjected to various types of corrosion test, have given no evidence of internal deterioration and have shown that any property loss is due to a surface attack. These facts are of practical importance, since the extent of corrosion can be estimated by visual inspection.

Where operating conditions are particularly severe, the metal should be given suitable protection. A number of commercial paints, varnishes and lacquers are satisfactory. The addition of aluminum-bronze powder generally improves the protective action of clear lacquers and varnishes. A preliminary treatment of the metal with a hot 10-per cent solution of magnesium or sodium acid-phosphate forms a surface that promotes adhesion of the protective coating.

TABLE 12—FATIGUE-ENDURANCE PROPERTIES OF MAGNESIUM AND ALUMINUM ALLOYS BASED ON 500,000,000 CYCLES OF THE ROTATING BEAM TEST

Magnesium Alloys	Fatigue-Endurance Limit, Lb. per Sq. In.		Aluminum Alloys
	Sand Cast Alloys		
Dowmetal *E*	8,000	8,000	No. 12 (SAE No. 30)
Dowmetal *A*	9,000	8,000	No. 142 (SAE No. 39) Heat-Treated
Dowmetal *A*, Heat-Treated	9,000	6,000	No. 195–4 (SAE No. 38) Heat-Treated
		7,000	No. 43 (SAE No. 35)
	Wrought Alloys		
Dowmetal *M*	9,000	7,000	3 *SO* (SAE No. 29)
		11,000	3 *SH* (SAE No. 29)
Dowmetal *F*	12,000	11,000	17 *SO* (SAE No. 26)
		15,000	17 *ST* (SAE No. 26)
Dowmetal *E*	14,000	8,000	25 *SO* (SAE No. 27)
		15,000	25 *ST* (SAE No. 27)
Dowmetal *A*	15,000	6,000	51 *SO* (SAE No. 28)
		11,000	51 *ST* (SAE No. 28)

Advantages

Magnesium alloys are rapidly rising into industrial prominence because they offer a combination of extreme lightness coupled with good physical and mechanical properties unsurpassed by any other engineering metal. A glance at Table 10 shows that magnesium is by far the lightest structural metal. It is only two-thirds as heavy as aluminum and has less than one-quarter the weight of steel. Table 11 gives the tensile properties of the more important structural metals, both in terms of pounds per square inch and also relatively on an equal-weight basis. Heat-treated magnesium-alloy castings are thus seen to have a tensile strength equal to that of heat-treated aluminum-alloy castings, while, on an equal-weight basis, the tensile properties of wrought magnesium alloys are equal to those of high-grade steel and of duralumin.

Another extremely interesting and important property of magnesium alloys is their high fatigue-endurance limit. Table 12 gives such data as determined by the rotating-beam test for cast and wrought magnesium alloys in comparison with the corresponding values for some of the more important and better-known aluminum alloys. The similar fatigue-strengths of these two groups are at once apparent and this means that magnesium alloys have a higher ratio of fatigue limit to weight than the aluminum alloys. This relationship is especially advantageous in the design of rapidly rotating parts, such as fan blades, airplane propellers and the like, as the centrifugal forces developed are dependent upon the weight of the rotating parts.

Commercial sand-cast magnesium alloys have a relatively high resistance to shock, as shown by their notched-bar impact-toughness values given in Table 13. This toughness is not accompanied by machining difficulties as might be expected.

TABLE 13—IMPACT TOUGHNESS OF CAST MAGNESIUM AND CAST ALUMINUM ALLOYS

Magnesium Alloys	Dow Impact Number,[1] Ft-Lb.		Aluminum Alloys
Dowmetal *E*	8	3	No. 12 (SAE No. 30)
Dowmetal *A*	4	3	No. 142 (SAE No. 39) Heat-Treated
Dowmetal *A*, Heat-Treated	10	10	No. 195–4 (SAE No. 38) Heat-Treated
		4	No. 43 (SAE No. 35)

[1] Pendulum machine with 5.9-lb. hammer. Cantilever specimen ½ in. square, with notch ⅛ in. deep and with 1/16 in.-radius.

In the design of most structures, the bending properties of beams, long columns or struts become an important factor. Tables 14 and 15 give the relative bending-properties for Dowmetal, duralumin and steel sections. In Table 14 the section thickness is the only variable, while geometrically similar sections have been considered in Table 15. These tables have been compiled to show how high bending-strength and stiffness for a given weight can be obtained by the use of light metals with a slight increase in dimensions and with a correspondingly large increase in the moment of inertia of the section. The calculated bending-strength

TABLE 14—RELATIVE BENDING-PROPERTIES OF DOWMETAL, DURALUMIN AND STEEL BEAMS OF CONSTANT WIDTH BUT VARYING THICKNESS

Material	t	t^2	t^3	Weight	Strength	Stiffness	Comparison
Steel Used as Basis of Comparison							
Steel	1	1	1	100	100	100	
Duralumin	1	1	1	35	60	33	Equal
Dowmetal	1	1	1	23	40	22	Thickness
Steel	1	1	1	100	100	100	
Duralumin	1.29	1.67	2.15	45	100	71	Equal
Dowmetal	1.58	2.50	3.94	36	100	87	Strength
Steel	1	1	1	100	100	100	
Duralumin	1.44	2.07	3.03	50	124	100	Equal
Dowmetal	1.65	2.72	4.55	38	109	100	Stiffness
Steel	1	1	1	100	100	100	
Duralumin	2.86	8.18	23.4	100	491	772	Equal
Dowmetal	4.35	18.9	82.3	100	756	1,810	Weight
Duralumin Used as Basis of Comparison							
Duralumin	1	1	1	100	100	100	Equal
Dowmetal	1	1	1	65	67	65	Thickness
Duralumin	1	1	1	100	100	100	Equal
Dowmetal	1.22	1.49	1.82	79	100	118	Strength
Duralumin	1	1	1	100	100	100	Equal
Dowmetal	1.15	1.33	1.54	75	89	100	Stiffness
Duralumin	1	1	1	100	100	100	Equal
Dowmetal	1.54	2.37	3.65	100	159	237	Weight

TABLE 15—RELATIVE BENDING-PROPERTIES OF DOWMETAL, DURALUMIN AND STEEL BEAMS WITH GEOMETRICALLY SIMILAR CROSS-SECTIONS

Material	d	d^2	d^3	d^4	Weight	Strength	Stiffness	Comparison
Steel Used as the Basis of Comparison								
Steel	1	1	1	1	100	100	100	Equal
Duralumin	1	1	1	1	35	60	33	Size
Dowmetal	1	1	1	1	23	40	22	
Steel	1	1	1	1	100	100	100	Equal
Duralumin	1.19	1.41	1.67	1.98	49	100	65	Strength
Downmetal	1.36	1.84	2.50	3.39	42	100	75	
Steel	1	1	1	1	100	100	100	Equal
Duralumin	1.32	1.74	2.30	3.03	61	138	100	Stiffness
Dowmetal	1.46	2.13	3.12	4.55	49	125	100	
Steel	1	1	1	1	100	100	100	Equal
Duralumin	1.69	2.86	4.84	8.18	100	290	270	Weight
Dowmetal	2.09	4.35	9.07	18.90	100	363	417	
Duralumin Used as Basis of Comparison								
Duralumin	1	1	1	1	100	100	100	Equal
Dowmetal	1	1	1	1	65	67	65	Size
Duralumin	1	1	1	1	100	100	100	Equal
Dowmetal	1.14	1.30	1.49	1.70	85	100	110	Strength
Duralumin	1	1	1	1	100	100	100	Equal
Dowmetal	1.11	1.24	1.38	1.54	81	93	100	Stiffness
Duralumin	1	1	1	1	100	100	100	Equal
Dowmetal	1.24	1.54	1.91	2.37	100	128	154	Weight

TABLE 16—PROPERTY DATA FOR DOWMETAL, DURALUMIN AND STEEL USED IN CALCULATING BENDING STRENGTHS

	Dowmetal	Duralumin	Steel
Young's Modulus of Elasticity, lb. per sq. in.	6,500,000	10,000,000	30,000,000
Tensile Strength, lb. per sq. in.	40,000	60,000	100,000
Specific Gravity	1.8	2.8	7.9

and stiffness values, based on the property data for Dowmetal, duralumin and steel, and on the usual beam formulas, are given in Table 16.

Strength in bending is directly proportional to the section modulus multiplied by the safe working-stress as expressed in the formula $M = (I/c)\ S$. The assumption is made here that the safe working-stress is proportional to the tensile strength of the beam material.

Stiffness in bending is directly proportional to Young's Modulus of Elasticity multiplied by the moment of inertia. It is the ability of a beam to resist deformation when stressed below the elastic limit.

From the above relationships we find that, for plates, sheets and sections where the thickness t is the only variable dimension, weight is proportional to t, strength in bending is proportional to t^2 and stiffness in bending is proportional to t^3. In similar sections with diameter, side or any linear dimension d, weight is proportional to d^2, strength in bending is proportional to d^3 and stiffness in bending is proportional to d^4.

A critical study of Tables 13 and 14 brings out many interesting comparisons and shows how these ultra-light magnesium alloys can be used to advantage where bending properties are a factor. The following examples serve to illustrate this point:

For equal strength in bending, Dowmetal sheet is 1½ times as thick, 40 per cent as heavy and 90 per cent as stiff as steel sheet.

For equal weight, Dowmetal sheet is 4½ times as thick, has 7½ times the bending strength and is 18 times as stiff as steel sheet.

For equal strength in bending, a Dowmetal beam is 40 per cent larger, 40 per cent as heavy and 75 per cent as stiff as a steel beam of similar cross-section.

For equal weight, a Dowmetal beam is twice as large, has 3½ times the bending strength and is 4 times as stiff as a steel beam of similar cross-section.

For equal strength in bending, Dowmetal sheet is 20 per cent thicker, 20 per cent lighter and 20 per cent stiffer than duralumin sheet.

For equal weight, Dowmetal sheet is 50 per cent thicker, has 60 per cent greater bending-strength and is more than twice as stiff as duralumin sheet.

For equal strength in bending, a Dowmetal beam is 15 per cent larger, 15 per cent lighter and 10 per cent stiffer than a duralumin beam of similar cross-section.

For equal weight, a Dowmetal beam is 25 per cent larger, has 30 per cent greater bending-strength and is 50 per cent stiffer than a duralumin beam of similar cross-section.

Uses

The commercial utilization of a new product usually begins by taking advantage of its most outstanding characteristics. In the case of magnesium, this means extreme lightness coupled with strength and toughness. Such a combination of properties at once suggests its application in portable hand-operated equipment, in high-speed reciprocating parts of machinery and in transportation industries. Impellers and blades in high-speed fans constitute other successful uses for this metal. Its light weight can be capitalized to good advantage in solving problems combating inertia and centrifugal forces.

The greatest interest in the possibilities of magnesium alloys is now displayed by the transportation industries, both automobile and aircraft. Fig. 16 shows a number of such applications of magnesium alloys, both in Germany and in this Country. The German Adler Standard 6, as illustrated, is equipped with numerous magnesium-alloy castings both in the engine and transmission and with disc wheels[8]. The total weight of these magnesium-alloy parts amounts to 162 lb., or a net saving of 220 lb. over the previously used aluminum and gray-iron parts. A still greater saving is possible in large motorcoach wheels, which are also illustrated. A complete set of these Büssing wheels weighs 280 lb. and replaces a set of steel wheels weighing 800 lb., thereby saving 520 lb. or 65 per cent. This enormous reduction in unsprung weight is at once reflected in greater acceleration and braking speeds, better road clinging, less pounding against the springs and less shimmying. All motorcoaches purchased by the Berlin Transportation Co. since 1926 have had such wheels as standard equipment. In addition to the advantages just mentioned, this company has found that these light-weight wheels gave up to 63 per cent greater tire life.

The demand for ultra-light weight construction parts is more urgent in the aircraft than in the automobile industry. Every pound saved in the weight of the airplane structure increases the payload or the cruising radius. Some of the more important applications thus far made include crankcases, housings, covers, fuel tanks, ribs, struts, wheels, sheet covering, furniture and trimmings. Illustrated examples of such applications include a riveted magnesium-alloy wing-section with rib profiles made from sheet metal[9], acetylene-welded oil and gasoline tanks for a Raab-Katzenstein airplane and an Albatros airplane that is equipped, not only with magnesium-alloy engine housing and wheels, but also with magnesium-alloy sheet coverings throughout. A 25-per cent saving in weight over former equipment was thus obtained in the Albatros airplane, and tests conducted with the cooperation of the German Research Institute for Aeronautics have shown that such construction can be advantageously used for land planes.

Magnesium alloys are helping to make history. Isotta-Fraschini in Italy[10] has used them extensively since 1925 in castings, pressed parts and profile sections. More than 2000 of its engines have been placed in service, chiefly in seaplanes, including those for the Italian marine. DePinedo had them in his two Savoia planes, the Santa Maria I and II, on his 27,000-mile trip to America and return. A machine of the same type likewise figured in the rescue of Nobile and his North Pole fliers. Fiat engines with magnesium-alloy pistons and castings captured the Schneider Cup in 1926 and helped Major Bernardi establish his 1927 world speed-record of 320 m.p.h. All of the 31 German airplanes participating in the 1930 All European Derby had magnesium-alloy parts[11]. Twenty-eight of them

[8] See *Deutsche Motor Zeitschrift*, vol. 6, p. 398 (1929); also *Metallwirtschaft*, vol. 8, p. 948 (1929), and *Elektronmetal-Nachrichten*, J/1, Nos. 1 and 2 (1928).

[9] See Fortschritte der Luftfahrt, 1929-1930 Jahrbuch, p. 414 and *Electronmetall-Nachrichten*, J/2, Nos. 3 and 4 (1928).

[10] See Wissenschaftliche Gesellschaft für Luftfahrt, 1929 Jahrbuch, p. 169, and *Elektronmetall-Nachrichten*, J/2, Nos. 1 and 2 (1927-1928).

[11] See *Zeitschrift für Metallkunde*, vol. 22, p. 317 (1930).

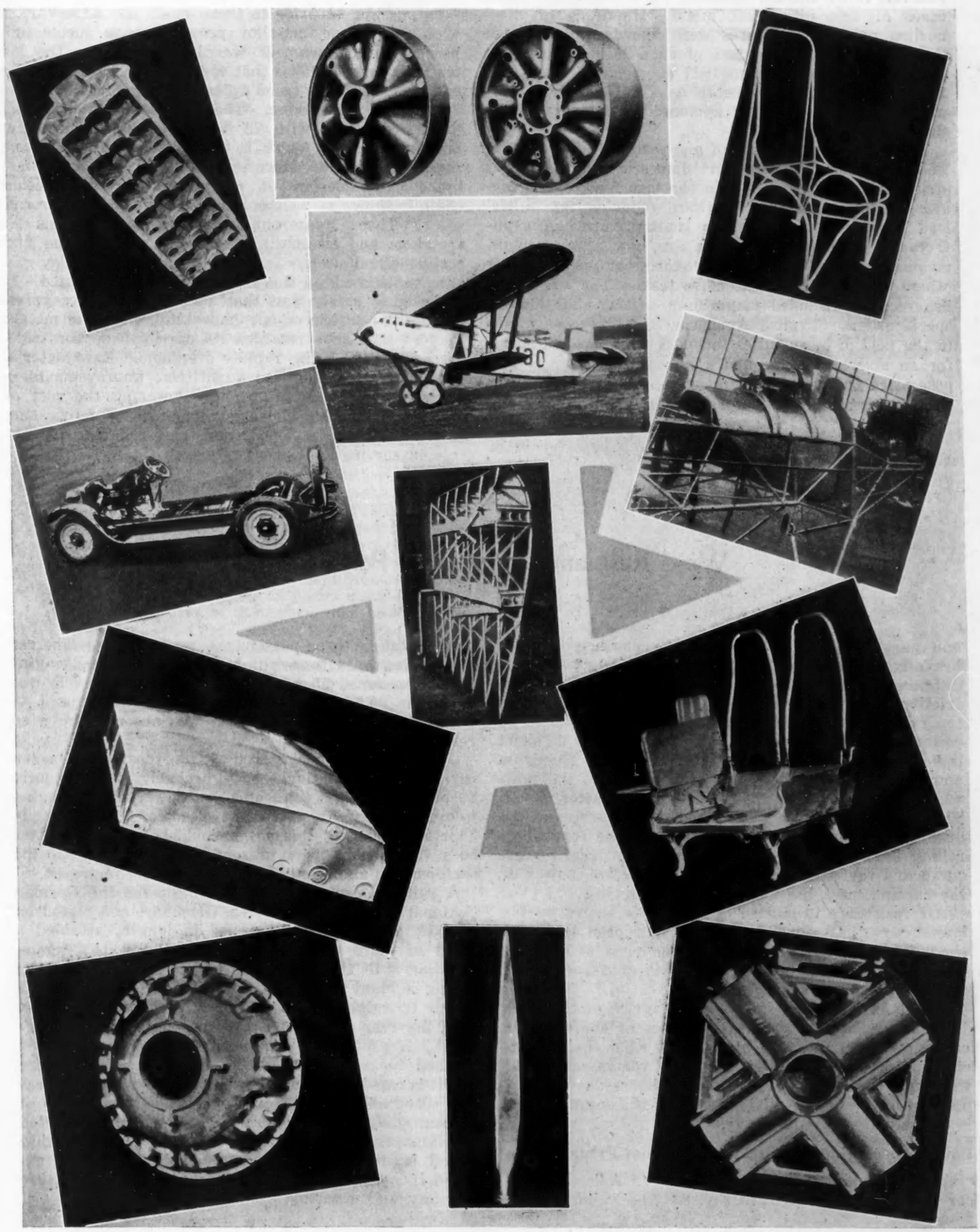


FIG. 16—APPLICATIONS OF MAGNESIUM ALLOYS TO THE AIRCRAFT AND AUTOMOBILE INDUSTRIES

had fuel tanks and 25, including the winner, had crankcases of this ultra-light metal. Hundreds of magnesium parts and fixtures were likewise used on the Graf Zeppelin. In the face of such facts, we are not surprised to read[12] that in 1927 magnesium constituted 10 per cent of the light metals used in German aircraft work, whereas in 1929 it amounted to 50 per cent of the light metals so used.

The fabrication and use of magnesium in Europe was well established when our domestic industry was struggling for existence. In the last few years, however, we have done much toward reducing this initial lead. At least 10 or 12 of the leading American manufacturers of aviation engines are now using certain magnesium-alloy parts as standard equipment, while others are conducting extensive tests. The Air Corps has recently included magnesium casting-alloys in its specifications. Typical American uses of these alloys in the field of aeronautics included a crankcase casting for an aircraft engine and a hub-wheel casting. The nose piece and propeller forgings shown are among the largest magnesium-alloy forgings thus far made. Information to date leads us to believe that our domestic forgings are superior to those made abroad. Various types of magnesium-alloy propeller have successfully passed the Government whirling tests[13]. In the last test, the forged blades that were designed for a 225-hp. engine successfully stood up under a load of 1600 hp., or 700 per cent overload. These propellers weighed 52 lb., as compared with 78 lb. for similar blades from aluminum alloys, which is equivalent to a 33-per cent saving in weight. More than 100 such blades are now flying. One design of magnesium-alloy motorcoach chair is shown as well as a still lighter weight aircraft chair. These represent successful applications of acetylene and electric spot-welding. One of the first acetylene and electric spot-welded magnesium-alloy gasoline tanks made in this Country is also illustrated.

We may safely say that industry now recognizes magnesium as one of our important structural metals. Factors that have retarded its development and widespread use are being rapidly overcome. Raw material is available in unlimited quantities; improvements in production methods are rapidly lowering the cost of the metal; suitable alloys and methods of fabricating them have been developed; and their reliable performance in service has been established.

[12] See *The Iron Age*, vol. 75, p. 470 (1930).

[13] See *Airway Age*, vol. 9, p. 32 (1928), and *Aviation*, vol. 29, p. 299 (1930).

Wind Resistance versus Car Performance

(*Concluded from p.* 635)

ond curve, indicating the effective engine-power, or brake horsepower, peaks at 104 hp. at 2050 r.p.m. The difference between the two curves therefore shows the friction loss in the engine. The difference between the curve of effective engine-power and the curve of power available at the rear wheels or at the axle shaft indicates the loss in the transmission gears. The drum power-curve shows the power transmitted to the rear-wheel rolling drum, or the chassis-dynamometer power. The space between the rear-wheel power-curve and the drum power-curve therefore represents the rear-wheel rolling loss. And the space between the drum power-curve and the curve of effective, or tractive, power of the car indicates the front-wheel rolling loss.

Air resistance to motion of the car is shown by the lowest curve. Obviously, maximum car-speed will be at the point where this curve crosses the curve of effective power of the car. In this case the intersection occurs at 134 km.p.h., or 83.75 m.p.h.

At the left in Fig. 8 is a power diagram of the Benz 100-hp. car showing percentage losses of the effective power of the engine, 104 hp. at 2050 r.p.m. being considered 100 per cent. Deducting the various gear and wheel friction and wind-resistance losses leaves 51.6 per cent of the total available power of the engine which is entirely absorbed by air resistance.

Power Absorption by Wind Resistance of Present Cars

A similar energy diagram taken on an Adler touring car is shown at the right in Fig. 8. The weight of the car, including three passengers, was 2900 lb. The car was driven by a four-cylinder 4 x 6-in. F-head engine which developed 75 hp., and the speed attainable was 71 m.p.h. The diagram shows that at this speed 48 per cent of the available power was absorbed by wind resistance.

Judging from the latter diagram, the modern sedan carrying a conventional body probably would require 80 per cent of the total effective power of the engine to overcome wind resistance at speeds of 65 to 70 m.p.h. Thirty per cent of this power could be saved by better body design even in the present type of vehicle, and the performance and economy would be much improved.

A railroad car that has been built for the German National Railway at Hanover, Germany, and tested on a track approximately 5 miles in length, attained a speed of more than 100 m.p.h. with 40 passengers. This car is of the coach type and is fully streamlined, having a blunt nose containing the driver's compartment. It weighs 20 tons, is 85 ft. long, and is driven from the rear end by an airplane engine and a large four-blade propeller. A speed of 124 m.p.h. has been attained for short stretches, and calculations indicate that it is capable of doing 185 m.p.h., for which tremendous speed an engine of only 400 hp. is required.

From study and consideration of the facts presented in this paper, sufficient reason exists for believing that radical improvements in motor-car design can be expected if speeds are to be increased with any measure of safety and economy.

Development of the Franklin *Direct Air-Cooled* Engine

Discussion of E. S. Marks' and C. T. Doman's Annual Meeting Paper[1]

FEATURES of the design of the various cylinders built by the Franklin organization in its development program leading up to the present design are discussed in this paper. The relation of waste heat to cooling-fin areas and cooling-blast velocities is shown and discussed for cylinders up to 3½-in. bore.

Characteristics of the cooling system, including fan, fan housing and air housings, are discussed at length, and the authors contend that no more power, if as much, will be absorbed in the cooling system as in that of the indirect air-cooled engine. Results of tests showing the engine's ability to cool under the severest conditions of load and temperature are given.

Since the quietness of any engine is dependent upon constant valve-clearances, the authors describe in detail the method followed in the Franklin design to maintain at less than 0.003 in. any variation in clearance. A careful analysis is made for each part in the valve-gear mechanism that is affected by expansion.

Power curves of earlier engines built by the company are compared with the present-production powerplant. Without a change in piston displacement, the brake horsepower at 3500 r.p.m. has been increased by 76 per cent. This increase has resulted from (*a*) better cooling characteristics of the cylinder, (*b*) increased valve area, (*c*) decreased absorption of power by the fan and (*d*) increased compression-ratio.

Discussers compliment the engineer-authors highly for their remarkable improvement in the air-cooled engine but are sharply divided into proponents of water-cooling and defenders of air-cooling. The former criticize the claim for freedom from detonation at the high compression-ratio used as being contrary to general experience with overhead-valve combustion-chambers, the spark-plug location, the peculiar valve-timing, the claim that power absorption by the fan is as low as that on water-cooled cars, and the assumed higher cost of production of air-cooled engines. They freely concede, however, that the work described in the paper on increasing the air-handling efficiency should stimulate like study by engineers working on water-cooled engines.

Defenders of the air-cooling principle relate their experience with air-cooled cars and claim that they have given more satisfactory service than water-cooled cars, as the cylinders have remained true and held compression better, the valves have not needed regrinding, and the engines start quickly on cold days and do not become too hot in summer. Water-cooled engines are said to run entirely too cool in many instances and the statement is made that the public will demand air-cooling because car owners do not want to bother with antifreeze solutions in winter.

The possibilities of air-cooling are said not yet to have been touched, and prediction is made that several more air-cooled cars will be in the market within the next few years. The Franklin valve-timing is said to be necessary for high speed and unobjectionable in combination with high compression. The spark-plug is said to be well located so far as detonation is concerned. Plumbing on water-cooled engines is stated to be a source of much trouble, and weight of the radiator and water is thought to bring the total weight of the powerplant up to more than that of the air-cooled engine. Costs of the two types of engine are thought to be comparable.

CHAIRMAN ALEX TAUB[2]:—One of the outstanding points that this paper brought out is that, if a vital improvement is made, the truth comes out. Heretofore we were not aware that anything was wrong with a Franklin. There are several phases of the subject that I think are well worth discussing. The authors claim that this engine operates at a 5.3:1 compression-ratio without any knock. This should inspire a few remarks from Mr. Janeway.

R. N. JANEWAY[3]:—The outstanding feature of this paper, in my opinion, is the demonstration by the authors of the tremendous possibilities for improvement in air-handling efficiency which lie in careful and intelligent investigation. In dealing with a direct air-cooled engine, in which the degree of success hinges upon the efficiency of air-handling, the authors have been forced to face the problem and overcome it. The data presented show that they have done a noteworthy job of blower development and air distribution.

These results should provide those engineers who are fortunately concerned with the indirect air-cooled engine with plenty of food for thought. I say, fortunately, because errors in air-handling are far less noticeable in the so-called water-cooled engine. In the first place, water, as a direct-cooling medium, automatically limits maximum metal temperatures by its boiling-point. In direct air-cooling, the only limit is the melting point of the metal. Secondly, in the ultimate heat transfer to air, the air-handling errors are blanketed by increased radiator size, which is limited only by appearance requirements. Recent trends toward narrower radiators, and at the same time increased engine output, are beginning to make apparent the crudities in air-handling which are more or less common in "remote" cooling, if still another term be admissible.

The volume of air-flow required in radiator cooling is considerably greater than in the case of direct air-cooling, because of the necessarily lower temperature-rise of the air for the same heat-dissipation. The power loss represented in handling this volume of air must

[1] The paper was published in the S.A.E. JOURNAL, February, 1931, p. 177. Mr. Marks is chief engineer and Mr. Doman is research engineer of the H. H. Franklin Mfg. Co., of Syracuse, N. Y. Both are members of the Society. The abstract printed with the paper is reprinted herewith, together with a summary of the trend of the discussion.

[2] M.S.A.E.—Development engineer, Chevrolet Motor Co., Detroit.

[3] M.S.A.E.—Consulting engineer, Detroit.

be reckoned with, both in the fan and in the air resistance to car motion. Considering the lack of attention that this problem has received in connection with radiator-cooled engines, it may reasonably be expected that intensive investigation will result in even greater power savings than Mr. Marks and Mr. Doman have effected. This prospect, together with the ragged-edge cooling being brought about by present design trends, should provide sufficient incentive for a concerted attack on this neglected problem.

The claims for one aspect of the Franklin-engine development, which was treated rather casually by the authors, seem so extraordinary as hardly to be taken as a matter of course. I refer to the absence of detonation, which, it is claimed, safely permits an ordinary compression-ratio of 5.3:1 and, if pressed, an increase to 8.5:1, which is quite satisfactory with commercial Ethyl gasoline. The authors state further that they have not done any combustion-chamber work other than to establish that the results with a single spark-plug could not be improved upon by the addition of spark-plugs up to a total of four.

R. N. JANEWAY

Antiknock Results Contrary to Experience

These results are so contrary to the general experience with overhead-valve combustion-chambers as to be not only interesting but revolutionary. In water-cooled engines of this type, the rule is that permissible compression-ratio is very sensitive to cylinder size, increasing rapidly as the cylinder volume becomes smaller. In the range of cylinder size of the engine described in the paper, namely 3½ x 4¾ in., permissible compression-ratio on domestic motor-gasoline would be in the neighborhood of 4.7:1, with cast-iron head, aluminum piston and single-plug firing at 90 deg. to the valves. An aluminum head should bring this up to about 5.0:1, and the addition of dual firing with opposing plugs would be required for a permissible compression of 5.3:1. As compared with this set-up, the Franklin engine has an air-cooled aluminum head and single-plug firing. Moreover, while the plug location is not stated, the illustrations indicate that it must be on the intake-valve side. Even if the air-cooling be considered as effective in this case as water-cooling, such a plug location is certainly far inferior to firing at 90 deg. to the valves, because the exhaust valve, which perhaps imposes the greatest limitation in this type of chamber, is more remote from the firing point. The authors admit that a plug location under the exhaust valve is superior for power; it would seem, also, to be the outstanding position for antidetonation. The only apparent reason for the plug location on the intake side in the Franklin design is the requirement of spark-plug cooling. However, it is necessarily a poor compromise so far as detonation is concerned.

The high-compression possibilities of this design are doubly hard to reconcile with experience because of the high brake mean effective pressure which is obtained by calculation from the power curve given in the paper. The possible reasons for the low degree of detonation obtained are actual overcooling under road conditions, retarded spark and relatively high antiknock quality of the gasoline. The use of Sunoco gasoline as a standard is, of course, a much more favorable condition than is imposed by the usually accepted grade of so-called "standard" non-premium gasoline.

Future of the Air-Cooled Engine

In connection with the power curves shown, comparing the new and old designs, it may be noted that the two curves are almost coincidental up to 1200 r.p.m. I find it difficult to understand how the marked improvement in breathing capacity and cooling, together with the increase of 0.6 in compression ratio could fail to yield an appreciable gain in the low-speed range unless it were entirely balanced by a shift to higher speed timing. Whatever the cause for this condition, it may, perhaps, also account for the absence of detonation.

The high engine performance which the authors have shown to be possible with direct air-cooling brings up the question of the future of this type of engine in the passenger-car field. This future must depend upon its fitness in the economic picture. Competition with the water-cooled engine is possible only on the basis of equal results per dollar, to use the apt phrase of Alex Taub. The cost factor seems to be a serious handicap for the direct air-cooled engine. The lack of compactness inherent in this construction is also a serious limitation, since the required length of fins surrounding each cylinder results in excessive engine length.

The future of the direct air-cooled engine seems to lie in the direction of an increased number of cylinders combined in the V-form. From the standpoint of engine length for a given displacement, breathing capacity, ease of cooling and compression ratio, the V-form of engine will have the greatest utility. The smaller cylinder-size, in itself, increases the ratio of valve size to displacement, gives higher surface-to-volume ratio for cooling and makes for higher permissible compression. It should also make possible the use of a smaller stroke-to-bore ratio within the limits of engine length, which makes for a sounder engine as well as still further increased breathing capacity without sacrificing compression ratio.

Some Doubts Created by Experience

LEROY V. CRAM[4]:—In 1922 the General Motors Corp. was greatly interested in air-cooling and I enjoyed the opportunity of putting into production an engine design that I had not fathered at all but that seemed to have great possibilities. The main difficulty we encountered was in getting a low-speed engine that would perform satisfactorily under all conditions, even on the deserts, and give high torque at around 800 r.p.m. We had plenty of detonation. The cylinders were very similar to those shown by Mr. Marks and Mr. Doman, so far as general arrangement of the valves and combustion-chamber is concerned. We gradually worked the compression down until we had compression ratios much lower than those in the new Franklin. However, we were in the position of trying to build a low-speed

[4] M.S.A.E.—Assistant chief engineer, Chevrolet Motor Co., Detroit.

rather than a high-speed engine, and, as one looks over these power curves of the Franklin engine, he wonders, in the light of experience, whether these engineers have not put a 5.3:1 ratio into it at 3000 r.p.m. and about 4.25:1 into it at 600 r.p.m. I should also like to have some information about the firing time and of the timing itself in connection with the low-speed work of the engine.

I think that the cooling arrangement is the cleverest thing I have seen in a long time. The authors of the paper have taken a very difficult problem, simplified it and really got some meat out of it. The change in passage shapes has reduced the air back-pressure very materially, which must of necessity have tremendously reduced power absorption by the fan. We fought that difficulty. We had fans similiar to the one they show as their latest design, and half a dozen other designs, but we did not have the freedom from back-pressure that they have secured, and consequently our fan load was not reasonable.

LEROY V. CRAM

One statement was made which I think needs answering; that is, that the absorption of 6.7 hp. by the fan at 3500 r.p.m. is as low as that of the conventional water-cooled engine. The usual water-cooled-engine fan-belt, if not helped by wind velocity, would not stand up for any length of time with the ordinary methods of drive. We have proved that time after time. The Harrison Radiator Corp. wind-tunnel has been subsidized on so much other work that we have not yet had an opportunity to find out how much horsepower we actually use at 60 m.p.h. with a 60-m.p.h. wind blowing against the radiator; but some time we hope to have some figures to show that the fan does not absorb very much power of the water-cooled engine. We are sure of it, but we do not know what the figures are.

After about 1½ years of intensive effort to put an air-cooled engine into production, we decided that we would go back to the first principles and build an engine without any attention being paid to previous proportions or details but embodying all the knowledge we then had. This engine was to be checked on its dollar value against a water-cooled engine of corresponding power. That was about a 12 or 14-month program, very carefully carried out by a man who had no ax to grind and who had no reason for getting one result instead of another, because all he had to do was to check two engines of given sizes with the most carefully designed work that he could do, so that we could find out where we got on cost. After having made that examination in the light of all the work we had done previously, the Chevrolet company decided that it would better stick to water-cooled engines, because it could thereby give the public considerably more for its dollar than it could give in the air-cooled engine.

CHAIRMAN TAUB:—There is a very interesting thought for the adherents of water-cooling. You do not know how much horsepower your fan absorbs. That sounds strange but it is true, and if you want to determine this loss accurately you will find that it requires considerable special equipment.

MR. CRAM:—We know that under many conditions the fan belt would not stand up if the power absorption were very large.

Air-Cooled Cylinders Remain True

J. A. ANGLADA[5]:—I dare say that we have all wondered why the Franklin company has so consistently adhered to air-cooling instead of devoting attention to building the more usual form of engine cooled with water. I think that it is to be congratulated upon having taken a stand and adhering to it, because it has proved the efficiency of direct air-cooling over a long period of public use.

About 1½ years ago, after having had some experience with air-cooled motorcycle engines, I decided to buy a Franklin car and gain more experience with direct air-cooling. I had previously owned various water-cooled cars for periods of two or three years for each car, and was prejudiced against air-cooling, but the Franklin car, which I have driven about 14,000 miles, principally over the hills of Pennsylvania, when compared with other cars of virtually the same piston displacement, leaves little to be desired from an operating standpoint. I do not know the compression ratio of the engine in my car but do know that it does not detonate when non-premium fuels are used, even when rapidly accelerating in high gear. I service my own car and can state that the engine in the Franklin car I am now driving has required less attention to keep it running satisfactorily than the engine in any of the water-cooled cars I have owned. For instance, on a cold day I can start out of a cold garage and in about three blocks the engine is up to a normal working-temperature, where full power of the engine is available without choking the carbureter, because the engine quickly reaches a suitable working-temperature.

In connection with direct air-cooling, I have recently been engaged in research on piston-rings. To test the sealing capacity of piston-rings, I rigged up an air-compressor, which has a displacement of 1½ cu. ft. per min., and arranged to connect the compressor quickly to the cylinder to be tested. After thoroughly warming up two water-cooled engines, I removed the spark-plug of each cylinder before the engines cooled noticeably and successively pumped air into each cylinder with its piston on the expansion stroke. The variation in the maximum air pressure obtainable in the different cylinders of these engines was from 20 to 70 lb. gage, and these pressures varied with the position of each piston relative to the stroke, showing variations in the sealing qualities of the rings at different parts of the stroke. Applying the same test to a Franklin engine, I found that the piston-rings held the compression better throughout the length of the piston travel, and I

J. A. ANGLADA

[5] M.S.A.E.—President, Anglada Motor Corp., New York City.

obtained higher pump-pressure values, showing that the rings were in better condition than those in the water-cooled cars tested. I also checked back on these results with a Harley-Davidson motorcycle engine and found that the uniformity of the cylinder bore was also more marked in its air-cooled cylinders than in the water-cooled automobile-engine cylinders. Therefore the impression I received is that correctly designed air-cooled cylinders provide a better fit for piston-rings and remain truer to form diametrically and axially than the water-cooled cylinders tested.

CHAIRMAN TAUB:—I think that you are a bit unfair. If I were going to make a check between an air-cooled and a water-cooled engine on the ability to hold air, I should get both as hot as they would get in service. Under those conditions I think that you would find out to what extent the cylinder-walls warp. If you chart the air seal of a cold water-cooled engine, you get one result; if you chart it for a warm engine, you get another result.

MR. ANGLADA:—You are absolutely right, but I should have stated that these engines were all at working temperatures.

CHAIRMAN TAUB: — How did you keep them that way with the plugs out?

MR. ANGLADA:—One can perform the test in a very few minutes, before the engine has cooled down appreciably, and a variation of 15 to 20 deg. should make little difference in the shape of a cylinder.

T. J. LITLE, JR.[6]:—I am afraid that the Franklin gentlemen may become discouraged at these facetious remarks from the water-cooled advocates. I think the Franklin engineers are not the only ones who can be criticized for making rather remarkable improvements after having gone a number of years without them.

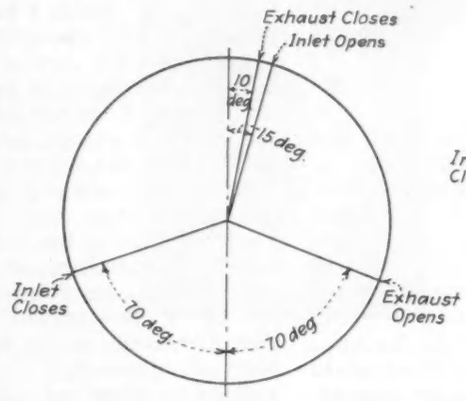


FIG. 1—VALVE TIMING AS OBSERVED ON THE 1931 FRANKLIN ENGINE

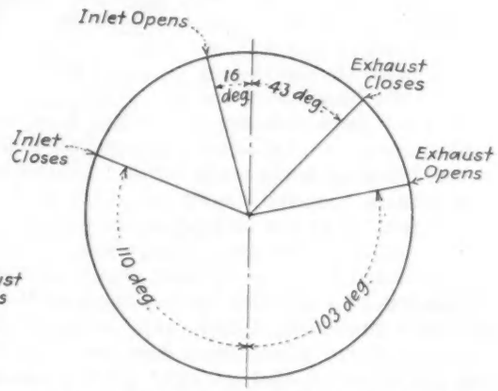


FIG. 2—DIAGRAM OF VALVE TIMING BASED ON FRANKLIN CAMSHAFT DRAWING

T. J. LITLE, JR.

Water is not ideal for cooling an engine. We have many instances of engines that run entirely too cool. Water-cooled engines are frequently ice-cooled in winter and steam-cooled in summer. I see no particular reason why the Franklin people should not progress even more rapidly in the future than in the past. They have the world before them as far as cooling is concerned. They need not necessarily be disturbed by the effort of the water-cooled engineer to build an air-cooled engine, because he does not know how to build one properly; and possibly if the Franklin people started building a water-cooled engine they would have as much trouble. When a group of engineers spend years on a problem, solving one problem after another, they, of course, could do better than without that background. Seriously, it is no wonder that the man who spends years in building a water-cooled engine would not succeed perfectly in building an air-cooled engine.

C. T. DOMAN

Regarding the power absorbed by the fan, that can be determined. Take off the fan belt and drive around the Indianapolis Speedway, and note the difference in speed. I think that the Franklin people really are to be congratulated on the work they have done, and I certainly hope they will continue. There are possibilities with air-cooling, in my estimation, that have not yet been touched. We cannot be very proud, surely, of the amount of plumbing we have on a water-cooled engine; of the radiator and of the volume and weight of water and the expense of building the radiator, water-pump, and so forth. I predict that in the next few years there will be several more air-cooled cars on the market.

ERIC GEERTZ[7]:—I should like to compliment the authors on the completeness of the information they have given with the power curve, including pumping losses and type of fuel used. Will Mr. Doman tell what is the percentage increase in the volume of cooling air delivered at, say, 3000 r.p.m. between the fan used on the series 135 and the new fan used on the series 15?

MR. DOMAN:—The 1931 fan delivers 7 per cent more air. The delivery curve is practically a straight line. Do you refer to the fan of the side-draft engine or the down-draft engine?

MR. GEERTZ:—I had in mind the characteristics of the 1931 fan.

MR. DOMAN:—The 12-in. fan pumps 7 per cent less air than the 1931 fan, which is 15 in. in diameter, and required 53 per cent more power to drive it.

[6] M.S.A.E.—Engineer and industrialist; vice-president, Holley Carburetor Co., Detroit.

[7] Jun. S.A.E.—Automotive engineer, Link-Belt Co., Indianapolis.

Unusual Valve Timing of the Franklin

With reference to Mr. Janeway's remarks about the high compression-ratio which we use on the new Franklin engine, we probably should have gone into this subject in more detail. One might infer that the engine has a combustion-chamber of unusual shape. The combustion-chamber is essentially the conventional overhead-valve type and is not responsible for the high compression-ratio used. The real reason that we can use the 5.3:1 ratio is the unusual valve-timing. The inlet valve closes very late and, as Mr. Cram said, our highest compression-pressures are at high speed, peaking at about 2250 r.p.m. The inlet valve opens 15 deg. past upper center and closes 70 deg. past lower center. The exhaust valve closes 10 deg. past upper center and opens 70 deg. before lower center, as shown in Fig. 1. This timing refers to that used on the production engine, which has the inlet valves set 0.003 in. and exhaust valves set 0.006 in.

CHAIRMAN TAUB:—Does that mean after the engine is heated by a long run?

MR. DOMAN:—No, the timing is essentially the same hot or cold. If the valve clearance varied with temperature, the valves would be either noisy when hot or hold open when cold. The diagram given in Fig. 1 takes into account the distortion of the valve-mechanism parts. If one should draw a timing diagram from a camshaft drawing, not taking into account distortion, he would think that the engine would not operate because the valve diagram then would be absolutely ridiculous. Such a diagram would be as follows: Inlet valve opens 16 deg. before upper center and closes 110 deg. past lower center; exhaust valve opens 103 deg. before lower center and closes 43 deg. past upper center, as in Fig. 2.

ALEX TAUB

Mr. Janeway also mentioned that perhaps, if more effort were expended on water-cooled fans and fan distributing systems, greater efficiencies would be obtained than are shown on the Franklin engine. As mentioned in the paper, we could obtain greater efficiency in the blower system if it were possible to use lower housings of larger proportions but, because of chassis limitations, it would be impossible to use this in the design. Furthermore, the increase in efficiency would come at high speed, where it again would hardly be noticeable in road performance.

I cannot see why an air-cooled engine could not be built at a reasonable cost provided an organization's policy was to build a low-cost engine. Certainly the cylinder-block could be cast as a unit and perhaps integral with the crankcase. I do not see that it should cost any more than the Chevrolet engine, except perhaps that the aluminum cylinder-head would cost slightly more than the radiator pump and parts which are necessary on the usual water-cooled engine. I have a Chevrolet car that some days runs as an indirect air-cooled engine, but seems to operate most of the time as a direct air-cooled engine. I will repeat the statement in the opening paragraph of the paper, that "fundamentally all automotive engines are air-cooled."

We have checked some water-cooled engines on the dynamometer without any air passing through the radiator and found that the fan and water-pump on a 320-cu. in. engine absorbed 8½ hp. at 3000 r.p.m. I do not know whether or not this is representative of most water-cooled engines.

CHAIRMAN TAUB:—That is about right, but unfortunately an automobile cannot be driven through the air without forcing air through the radiator.

MR. DOMAN:—Do you mean that the fan would take more power with the car in motion?

CHAIRMAN TAUB:—No, the air drives the fan.

MR. DOMAN:—We find that the Franklin fan delivers about the same volume of air on the road as it does in the dynamometer room. Apparently the resistance of the hood front is about equal to the increase in air-flow due to passage of the car through the air, so we assume that the dynamometer-room results are the same as the road results.

Speaking about the losses past the piston-rings, you suggested getting both cars as hot as they will get. What did you mean by that? To test a water-cooled car when it was as hot as it would get, you would test it after you had boiled out all of the water.

CHAIRMAN TAUB:—I meant operating temperatures.

Mr. Litle was wrong again. We can design air-cooled engines without even trying, because Mr. Doman says his Chevrolet operates as an air-cooled engine right along.

The Franklin timing diagram is significant. Closing the intake valve 71 deg. past lower dead-center will push out a large percentage of the charge at low speed. I think that Mr. Cram's deductions on this probably were correct.

G. M. BICKNELL[5]:—Thermostats, shutters and other means are used with water-cooled engines to help warm them in winter. When I worked on the air-cooled experimental jobs at Chevrolet we had as much trouble warming up the engine in the winter as we had with its getting too warm in the summer. What does Franklin do about warming up in the absence of thermostats?

MR. DOMAN:—We have a thermostat on the hood-front shutters. We also use an aluminum gasoline vaporizer which permits the intake gas to warm very fast.

CHAIRMAN TAUB:—In other words, the accessories are coming into the air-cooled side of the picture.

Comparative Weights of Two Types

QUESTION:—What are the comparative weights of air-cooled and water-cooled engines?

MR. DOMAN:—I do not know, but we are of the opinion that the air-cooled engine is about 50 to 100 lb. lighter, taking into account the radiator and the water in it and the other accessories. The engine which I have just discussed weighs 747 lb. with clutch, transmission and all accessories. Remember, however, that this includes all the cooling system.

CHAIRMAN TAUB:—What is the piston displacement?

MR. DOMAN:—It is 274 cu. in.

CHAIRMAN TAUB:—A weight of 747 lb. for 274 cu. in. is not difficult to equal in water-cooled engines. Perhaps the Marmon engine will give a satisfactory answer

[5] M.S.A.E.—Chief engineer, Carter Carburetor Corp., St. Louis.

to that question. The new 16-cylinder engine is a relatively light engine, with a generous use of aluminum. Aluminum has been necessary in the Franklin construction. It has been used advisedly, too, and serves to cut down the weight.

MR. LITLE:—What did the Chevrolet air-cooled engine weigh?

MR. CRAM:—Does anybody here remember what his 1922 powerplant weighed? I do not.

CHAIRMAN TAUB:—One of the fundamental advantages of the air-cooled engine has not been mentioned so far; that is, it is possible to operate at very high temperatures. This is a distinct advantage for aviation work, but water-cooling is being supplemented by steam-cooling or evaporative cooling, combined with a special cooling-medium. Engines have been operated at a cooling-medium temperature of 300 deg. fahr.

Solution of Distortion Problem Worth Study

F. G. SHOEMAKER[9]:—I am much interested in this engine, having been connected with the Franklin company at the time these engines were in their early stages of development, and I fully appreciate the remarkable work that Mr. Doman and Mr. Marks have done in devising a scheme for compensating for all the variations that come in air-cooled engines. This experience can be looked over very carefully by water-cooled engineers to solve the same problem.

An important factor that has been entirely overlooked in most overhead-valve engines is that of distortion of the valve gear. This accounts in a measure for what is regarded as radical if not absurd valve-timing in the Franklin engine. The timing arrived at is necessary to get power at high speed, and I see no objection to using it and a high compression-ratio at the same time. This tendency is creeping into the high-speed water-cooled engines, so the Franklin engineers need not apologize for the somewhat unconventional valve-timing nor for the fact that they close the inlet valve late and thereby are able to use a high compression-ratio.

Mr. Taub, I believe, infers from the drawings that the spark-plug location is on one side of the cylinder. Unless it has been moved recently, I believe that the spark-plug is in the center line of the cylinder, virtually midway between the valves, and could scarcely be in a better position as regards detonation.

F. G. SHOEMAKER

MR. DOMAN:—Mr. Shoemaker is correct in his statement concerning the spark-plug location. The spark-plug is located in the cylinder-head on the center line of the engine. We have found recently, however, that a horizontal plug located immediately under the exhaust valves gives slightly more power and less tendency to detonate. This is a natural result since, according to change of theory regarding combustion, the last charge to burn would be cooled on the blast side of the combustion-chamber. By blast side I mean the side of the chamber upon which the cooling air is directed.

[9] M.S.A.E.—Research engineer, powerplant section, General Motors Corp. Research Laboratories, Detroit.

[10] Patent attorney, Holley Carburetor Co., Detroit.

Aircraft Air-Cooled Engine Development

CHAIRMAN TAUB:—Do not misunderstand us. We do not feel that the Franklin people have anything to be ashamed of in this job; we think rather that they should be congratulated. Whether location of the spark-plug in the center of the cylinder is the most ideal with respect to detonation is a question. It is very difficult to say exactly what is the ideal location for a plug for antidetonation in engines that are very similar, and it is extremely difficult to predetermine a spark-plug location for an engine so vastly different as the Franklin engine is.

S. D. HERON

Mr. LITLE:—Why do air-cooled engines rather than water-cooled predominate in aircraft? It occurs to me, too, that one of the slogans the Franklin company might aptly adopt is, The air-cooled engine never runs out of air but the water-cooled engine sometimes runs out of water.

S. M. UDALE[10]:—The history of the British and French air-cooled engine prior to and during the World War is briefly as follows:

First.—Bleriot flew the English Channel (Straits of Dover) with a fixed radial Anzani engine. This was a much more important milestone than Lindbergh's flight.

Second.—The Seguin brothers developed the Gnome and LeRhone rotary radial engines.

Third.—At the outbreak of the war the Renault V-8 and the Monosoupape (Gnome) rotary were substantially developed. These engines were therefore put into immediate production.

Fourth.—The Clerget then appeared and "did the trade" for quite a period at the front.

Fifth.—After introducing aluminum pistons to these engines, Bentley developed the aluminum cylinder for rotary engines.

Sixth.—Bradshaw then developed the A.B.C. radial engine.

Seventh.—Major Greene, assisted by S. D. Heron, developed the Siddeley Deasey, now known as the Armstrong Whitworth, Lynx, Mongoose, Jaguar and Genet engines, which have a cylinder-head somewhat similar in design to the Wright engine designed by C. L. Lawrance.

All who had experience with the maintenance of airplanes that were active on the Western Front know that the air-cooled engine demonstrated its superiority from a military point of view. As proof of this, I, with the help of one mechanic, have without previous instruction pulled down a Monosoupape rotary air-cooled engine in 25 min. and rebuilt it in less than 2½ hr. Secondly, I have seen a plane fly back with a cylinder put out of commission by shrapnel, the other eight cylinders carrying on as though nothing had happened. Also, the delay

in warming up water-cooled engines had disastrous results when an emergency call came.

S. D. HERON[11]:—As far as my knowledge extends, Mr. Udale's statements as to the history of progress are substantially correct, with the important exception that he omits all mention of the work of Dr. A. H. Gibson at the Royal Aircraft Factory.

Under Major F. M Green, at the Royal Aircraft Factory, the RAF-1 and RAF-4 engines, with cast-iron F-head cylinders, were developed by 1914. These engines represented somewhat of an improvement over the Renault engines as regards cylinder cooling. Major Green, however, realizing that knowledge of cylinder cooling in general and of air-cooled cylinders in particular was almost negative, secured the services of Dr. Gibson for a general investigation of cylinder cooling and all phases of engine cooling. Dr. Gibson's work resulted in a vast increase of knowledge of the problem of casting high-speed-engine cylinders in general and in the production of cylinders for aircraft engines which were, for the first time, really air-cooled rather than fuel and oil-cooled. It is from the air-cooled cylinders produced at the Royal Aircraft Factory during Dr. Gibson's investigation that the modern efficient air-cooled cylinder of high output has grown.

A Better Cooling Medium Needed

CHAIRMAN TAUB:—If one could design an air-cooled engine with fewer "bugs" than there are in the water-cooled engine, we would certainly advocate the former type. There is no doubt today that we are restricted in our efforts on water-cooled engines by the simplest thing in the world. Our progress is materially affected by the lack of a proper cooling-medium, particularly in the winter. We still operate the engines hot in summer and cold in winter because we do not have a trustworthy fairly-priced anti-freeze. Our choice lies between low boiling-point and seepage. Water-cooling incorporates definite difficulties. Nevertheless, my personal opinion is that there are fewer problems to overcome in the water-cooled engine. The Franklin engineers have been working on the air-cooled engine for years, yet in 1929 they still had an unsatisfactory job, according to their own evidence.

H. C. DICKINSON

MR. DOMAN:—I take exception to Mr. Taub's last statement. Apparently all engineers feel that their cars are not satisfactory, for each year sees a crop of entirely new designs.

J. OTTO SCHERER[12]:—Mr. Taub criticized the tests for blow-by in the warm engines. Pardon me for mentioning Buick engines, but I have driven Buick cars for about 10 years. Those water-cooled engines were notorious for blowing oil out through the crankcase ventilator until it was led out below the drip pan; then you could not see it any more.

CHAIRMAN TAUB:—That is true. But why pick on Buick? They all blow by. That is why I questioned the test. The element that maintains the compression is the oil seal that results from the cycle of operation. Without that you cannot expect a seal.

[11] S.M.S.A.E.—Research engineer, Air Corps, Materiel Division, Wright Field, Dayton, Ohio.

[12] M.S.A.E.—Consulting engineer, Detroit.

Plumbing Is a Source of Trouble

MR. ANGLADA:—We should not be too prejudiced against direct air-cooled engines, because the first thing we know we shall work ourselves out of jobs if we insist upon not having an open mind. For a long time we had been saying "free-wheeling is not practical," but now several companies are using free-wheeling constructions. I think we should consider direct air-cooling more seriously than we have done, for several good technical reasons and, further, because the public does not like to fuss with antifreeze mixtures in the winter.

Moreover, the performance of the present Franklin direct air-cooled engines and of motorcycle engines in the hands of the public is satisfactory. The public will become more generally educated to the advantages of direct air-cooling when other companies besides the Franklin build air-cooled cars, because I think the results that we shall be able to get from air-cooling will be superior to those we have been able to get from water-cooling so far as maintenance is concerned. Also, the weight and cost of the powerplant including the radiator need not exceed the weight and cost of the water-cooled powerplant. We found this to be the case in the aviation industry. Most engineers who have had experience with water-cooling and air-cooling in aviation will state that the air-cooled powerplants give less trouble over a long period than does the water-cooled equipment because, with water-cooling, we have the plumbing as well as the engine to consider.

MR. CRAM:—I wonder how many who are talking about the predominance of air-cooled engines in aircraft take into account the ease of cooling a radial engine traveling at double the automobile speed, with every cylinder sticking out in the atmosphere, as against a Franklin six-cylinder in-line engine and the plumbing necessary to take care of the cooling in that condition.

Comparative Engine Temperatures

MR. DOMAN:—Some reference was made to the air-cooled engine as being necessarily high in operating temperature. The part that any engineer must watch the closest in the combustion chamber of any engine, either water or air-cooled, is the exhaust valve temperature. We find that our exhaust valve is not any hotter than, if as hot as, that of a water-cooled engine. I doubt whether the skin temperatures of the Franklin combustion-chamber or cylinder-wall are any higher than those of the average water-cooled engine. A water-cooled-engine man told me that he was getting 280 deg. on his cylinder barrel just beneath the water-jacket. That is not much different from the Franklin cylinder at the same location. When some people speak of air-cooling they always think of the engine as being hot. No doubt this impression is carried over from the early days.

CHAIRMAN TAUB:—You should bear in mind that the Franklin has not always been as good as it is now, and we have not had experience with the new engine. The chances are that with more contact with this new Franklin, as it has recently been developed, the respect for air-cooling will be greatly enhanced.

MR. SCHERER:—One respect in which I think air-cool-

ing is superior to water-cooling has not been mentioned. Many water-cooled engines go to farmers who fill the radiators with hard water. Most water-cooled cars are bad knockers after three or four years of life and do not give good performance. One reason is that the water-jacket becomes coated with limestone, which is an effective heat insulator. An air-cooled engine, no matter how old it is, will maintain its cooling. If anything goes wrong with the cooling, it is due to oil and dust clogging the fins, and that accumulation can be washed out. An old air-cooled engine is much more likely to maintain its original performance than is an old water-cooled engine.

MR. CRAM:—I have had to use a hammer and chisel to get that oil and dust out.

EDWARD D. HERRICK

H. C. DICKINSON[13]:—I have been much startled to learn how bad the old Franklin engines were, because I drove one of them for a long time. Any motor-car design is a matter of compromise. The old Franklin engine, which produced perhaps a maximum of 25 hp., delivered exceptionally good performance. It would not drive the car very fast. The valve mechanism probably expanded and contracted 0.050 in. Nevertheless, my car ran 40,000 miles without regrinding of the valves, which were perfectly good at the end of that mileage. The car was not driven very carefully. It was driven 700 miles one day and 400 to 450 miles a day at various times. Without any particular provision for it, the engine warmed up on the coolest day in about 3 to 5 min. under usual operating conditions. It was a little too cool at high speed, and never was known to get hot in summer. The only time the old engine knocked, as far as I know, was when the fins became filled with June bugs that had to be blown out about once in two years; otherwise it did rather well. If the new ones are as much better than the old ones as this paper would indicate, I certainly should like one.

Production Cost Believed Too High

EDWARD D. HERRICK[14]:—I feel that advantages are to be had with both types of cooling. One can always find fault with something about either type of engine. In the final analysis, I believe an air-cooled engine can be made as efficient, within reasonable limits, as the water-cooled engine, provided it can get sufficient air to cool it. The power required by the fan to increase the flow goes up rapidly, but it is possible to produce a very efficient air-cooled engine and bring the brake mean effective pressure within the present-day limits. That operation in an automobile is not entirely analogous to that in the airplane.

Another thing I feel sure of is that an air-cooled engine is not as economical to produce with present manufacturing methods as is a water-cooled engine. The materials of construction are essentially higher in cost. After all is said and done, we are trying to produce powerplants that will accomplish certain results at minimum cost. Water-cooled engines seem to have decidedly the advantage in this respect.

A. F. DENHAM[15]:—On p. 4 of the preprint of the paper (p. 180 in the S.A.E. JOURNAL for February) the cooling area of the cylinder-head is given as 7.22 sq. in. per cu. in. of piston displacement and 34.1 sq. in. per b.hp. output. That would give a horsepower output of about 0.2 per cu. in., whereas the specific horsepower figured from the power curve in Fig. 14 works out at 0.3. Evidently something is wrong with the figures.

Also, I should like to ask how the specific fuel-consumption of the 1931 engine compares with that of the 1930 powerplant.

MR. DOMAN:—I am glad that Mr. Denham discovered the error in the relation of cooling area to piston displacement and brake horsepower as given in the paper. The correct figures should be 10.8 sq. in. of cooling area per cu. in. of displacement and 34.1 sq. in. per b.hp.

Offhand, there is not much difference in specific fuel-consumption between the two engines, except in the upper speed-range, where the decreased power absorption of the new fan helps the fuel economy. The same carbureter and intake system is used on the 1930 and the 1931 engines.

MR. DENHAM:—What is that figure?

MR. DOMAN:—I have not the exact figures on hand regarding fuel consumption; however, the average should be about 0.65 lb. per b.hp. This goes to show that we do not depend upon a wet mixture to keep the engine temperature at a low figure.

CHAIRMAN TAUB:—I certainly want to join with those who have congratulated the authors on their work. I believe that, if the water-cooled-engine designers could make as much progress between two given models as the Franklin engineers have indicated in their paper, it would be wonderful. That is something for us all to think about.

[13] M.S.A.E.—Chief, heat and power division, Bureau of Standards, City of Washington.

[14] M.S.A.E.—Chief engineer, Lycoming Mfg. Co., Williamsport, Pa.

[15] Field editor, *Automotive Industries*, Detroit.

Operators' Future Motor-Truck Requirements

By James C. Bennett[1]

Annual Meeting Paper

FIVE REASONS are listed and briefly discussed for the trepidation felt by the author when consenting to present his views on the subject as a fleet operator. He feels, however, that large-scale operators encounter the same varying conditions as are met by the other operators; that if specially equipped chassis are excluded, little need exists for demanding specially designed chassis; that the truck manufacturer is alert to adopt improvements and that operators' fleets are an ideal proving ground; that the really significant division of the field of operations is the intensity with which the equipment is used and that, hence, the questions to be answered are those of productive life on the one hand and of obsolescence on the other; and, finally, that cost accounting should be based on ton-miles of carrying capacity rather than on loads actually carried.

The author does not advocate higher maximum-speed, but desires greater capacity for sustained speed. Three much desired improvements are: (*a*) interchangeability of major units of the chassis, (*b*) reduction of chassis weight and (*c*) greater uniformity in space available for body mounting or load-carrying facilities. Each of these is discussed in some detail.

According to one of the discussers, interchangeability of units in large fleets is highly desirable, but it has not been accomplished to any great extent between competitive makes of truck. Factors of present important problems of design are stated by another engineer, and a third explains how forecasts of future designs are hampered by changing conditions. Economy of manufacture and quantity production make necessary adherence to definite standards in construction which will give efficient operation over the greater maximum mileage for which the design is contemplated, according to another statement. In conclusion, present unfavorable legislative trends in various States are cited and the unfriendly attitude of the railroads toward the motor-vehicle is deplored.

FOR SEVERAL reasons I consented with considerable trepidation to discuss the subject that has been assigned to me. At least some of those reasons seem of sufficient importance to justify their enumeration and brief discussion before giving specific consideration to future requirements of motor-trucks.

First, what are commonly termed fleet operators, and particularly those of National scope, are known to comprise but a very small portion of the entire field of truck operations. That the proportion of the large-scale fleet operators is about 10 per cent of the whole seems a reasonable estimate. If this figure be accepted as appropriate, we see that the operators of large fleets may possibly place greater importance on their experiences than the truck manufacturer may feel justified in recognizing. However, in justification of the large-scale operator's impression of the importance of his experience, probably, in the composite, this group covers rather well the varying conditions under which the remaining 90 per cent of the trucks of this Country are being operated.

Second, operators seem somewhat prone to believe that their problems are peculiar and, hence, justify features of special design in the chassis they use. I am under the impression that this may possibly apply more to the operators of large fleets than to those of a very small number of trucks. I am convinced that, if we exclude specially equipped chassis such as those used for carrying special types of mounting, as dump trucks, concrete mixers, welding sets and so on, little reason exists for any of us to call for a specially designed chassis. We may find some feature incorporated in one chassis which is not in another and may, therefore, select the one in preference to the other, but this is very different from insisting that special features be built into any chassis.

Third, truck manufacturers evidently are much alive to the advantages to be realized by being continually alert to adopt such improvements as may be developed, either by themselves or as a result of operators' experience. I believe that the function of an operator is not to design chassis equipment; he can find troubles enough in keeping his head above the water of operating problems without attempting to usurp, or even to encroach upon, the natural functions of the manufacturers. Operators undoubtedly can contribute much to their own advancement, however, by working closely with the manufacturers and recognizing continually that the operator's fleet furnishes the manufacturer with an ideal proving ground. If operators will rely upon the manufacturer to analyze the results of their experience and to adopt and incorporate in his design such features as their experience shall have shown him to be desirable, I am confident that both manufacturer and operator will realize a substantial benefit in a comparatively short time.

Degree of Intensity of Operation

Fourth, while many and diverse conditions exist under which operations are carried on, such as in mountains as compared with flat country, unpaved versus paved roads, country versus city traffic and so on, I be-

[1] M.S.A.E.—Manager, automotive department, Associated Oil Co., San Francisco.

lieve that, from the manufacturer's standpoint at least, the entire field has only one really significant division. This division is determined by the intensity with which equipment is used. Speaking rather broadly, the operator whose fleet is engaged in contract or transport hauling has to deal with a degree of intensity that may cause his selection of trucks and the demands he may make upon them to be very different from the choice of, and demands upon, trucks used in the second subdivision. The second group is composed of operators who are using trucks as an incident to their general enterprise. In this field the truck is used as a medium of distribution rather than of pure transportation. In many instances the activities of these trucks are seriously restricted in that much of their time proves to be entirely idle. In short, they are serving in the dual capacity of carrying freight and a lone salesman or solicitor.

To the manufacturer, the outstanding characteristic that may determine the grouping I have just described will be that the former, because of the high intensity of use, will easily justify the purchase of equipment that is built for long life in terms of miles. For equipment in this class the life in terms of time may be regarded as essentially negligible. Ample reason exists for the operator to expect to realize the maximum potential life of the machine long before obsolescence lifts its head. For service in the second division, however, the problem of both the operator and the manufacturer becomes entirely different. Here the operator is confronted with the probability that, if he hopes to realize the maximum potential life of his equipment in terms of miles, he will have to face the effects of obsolescence pure and simple. For example, the operator whose trucks are employed in contract or transport hauling from one city to another, even though he may collect and distribute from door to door, will easily realize from 4000 to possibly 6000 miles per month for each truck. In contrast, the operator whose equipment is used for the retail distribution of his product, whether it be bread, milk, oil or other similiar commodity, probably will do well if he averages 1500 miles per month for each unit. The time lost at each stop is so great that it becomes almost impossible to operate his trucks with any degree of intensity.

Truck-Life Comparisons Made

For the present purpose let us consider a truck that is entirely capable of rendering satisfactory and economical service over a life of 250,000 miles. If two operators, one in each of the classes just indicated, are in the market to buy a truck, and assuming that both buy the same quality, the first operator will have availed himself of the full potential life in somewhat more than four years. As against this, the second operator must expect to operate his truck nearly 13 years before he can have realized the full return on his investment. The fact then becomes evident that the first operator should have little question in the purchase of equipment into which has been built the maximum number of miles. The second operator, however, finds himself faced with a question that is not so easily settled.

The particular point that the second operator is required to determine is, will his inability to realize the maximum life of the high-grade truck cause him to carry so high a rate of depreciation as to offset the probable lower operating expense that may be characteristic during the enforced shorter mileage life of the high-grade equipment? As against this question, the truck that can be purchased for a slightly lower initial cost will for some time incur an operating expense which may be closely comparable with that of the truck of higher quality. Hence, during the initial period of the truck's life, a safe assumption is that the lower-priced truck will seem to be the more economical; but the entire life of both trucks must be considered. At some point in the lives of both trucks mechanical failures, and attendant loss of productive time, will become increasingly frequent and, either simultaneously or soon afterward, the unit cost will take a somewhat sharp upward turn. From one or both of these points on, the purchaser is required to balance the relative merits of the two. In fairness to all trucks this is a rather nice point to determine, and to develop the question further at this time does not seem appropriate.

Fifth and last, but by no means the least, of the factors that should cause an operator to be somewhat cautious about indicating too great a degree of assurance in expressing his views as to the prospective requirements of trucks, is the fact, which has been all too frequently demonstrated, that comparatively few operators really know the various elements entering into their costs. I recognize that I am touching here upon an extremely delicate point. Each of us, as operators, feels assured that he has a system of cost accounting which is fully adapted to the needs of his operations and, further, that his system covers all items which can have any substantial bearing on his own experience. However, let us defer further consideration of this point until later. I believe it to be a really vital question and one that merits some expression of opinion.

Sustained versus Increased Speed

The several points discussed thus far should serve to qualify such expression as may be made regarding future requirements, at least to the extent that I realize that the prospective requirements, from the standpoint of the operator, must be tempered by a recognition of the problems and ambitions of the truck manufacturers.

Probably a safe assumption is that many who may read this discussion have taken for granted that a plea will be made for greater speed. For an author possibly to disappoint his audience is regrettable, but this point does not seem to me to be of paramount importance. Rather than to call merely for increased speed-capacity, I lay stress on the desirability of improving the capacity for operating under sustained speed. This is perhaps of secondary importance for trucks in city service, but for those operating through the country on the open highways the ultimate interpretation of speed is becoming rather generally recognized to be in terms of the time elapsing between the start and the finish of a run. That this over-all time does not necessarily imply an excessively high speed for even short periods is also rather generally recognized. However, in establishing any schedule for operation the owner should be justified relying confidently upon the ability of his trucks to maintain a fairly high speed as long as the traffic conditions will reasonably permit.

In pointing out this distinction I have in mind the question of expense to be incurred as a result of calling for long-sustained speed on the truck's run. Manifestly, we may impose a great burst of speed on a truck and, as this would be for but a short period, we may do no appreciable damage to the machine, but we all know that if the high speed is maintained for a considerable

period, we must expect to pay the bill in terms of fuel consumption and of machine maintenance. This latter item in particular is the one with which we should be especially concerned. In general, I believe that we shall be able to realize increased speed just as rapidly as the general conditions of highways and traffic make such increase feasible or permissible. Therefore we may safely leave this question to the truck manufacturer, who, I believe, will provide such quality as rapidly as the general economics of the entire field will offer any inducement for him to do so.

Another item is that of the braking equipment of trucks. Both manufacturers and operators are aware that we are imposing demands upon our present trucks which are somewhat in advance of the provision that has been made in terms of braking capacity. We have ample evidence, however, that the manufacturers are fully alive to this need and are continually working on the problem of improvement.

In the course of my duties as one responsible for supplying and maintaining a fleet of approximately 1000 vehicles, of which about three-quarters are trucks, I have become acutely conscious of three factors that still leave much to be desired. These are:

(1) Interchangeability of major units of the chassis
(2) Reduction in chassis weight
(3) Greater uniformity in the space available for mounting, or load-carrying facilities

These factors seem to be of about equal importance and, further, to be of nearly equal importance to the manufacturer and the operator.

Interchangeability of Major Units

The operator who is fully alive to his problem realizes quickly that, from the viewpoint of revenue and possible profit, a truck continues as an asset only so long as its wheels are turning. The moment the wheels stop, the vehicle is transformed from an asset to a liability. Hence, one of the first goals of the operator is to keep a truck continuously in service.. That much can be, and in fact has been, accomplished in this direction is well demonstrated by the experience of the last four years in connection with the fleet with which I am at present concerned. Four years ago a common experience was that a truck must be withdrawn from service for 30, and possibly for 45, days in the year for periods of general reconditioning. The common practice also was to withhold a truck from service from 15 to 25 days for repainting. I have not obtained the figures for the latest period; but, in the first six months of 1930, the average time out of service for a fleet of 760 trucks was 1 day out of each 45 calendar days, for each truck. This included the time required to repair because of accidents and for repainting in addition to the normal reconditioning of the vehicle. In passing, I may mention that this particular fleet is operating over a wide area and is divided into groups ranging from 1 to 45 or 50 vehicles for which headquarters are provided at approximately 125 different cities and villages on the Pacific Coast. Largely through the use of exchange units, such as engines, transmissions, rear ends and generators, we have almost eliminated the periodic overhaul.

The operator who attempts to realize interchangeability as between chassis of different weight-carrying capacities will, I believe, ultimately find himself somewhat misled because of a fallacious line of reasoning. He should not be unduly concerned, either, with interchangeability as between the details of any given unit. This will be touched upon again later. The fact has been clearly demonstrated, at least in my own experience, that the use of exchange units offers a tremendous advantage in terms of operating time to be gained. Assurance that all units in trucks of a given weight-carrying capacity should be interchangeable, not only today but also perhaps for some years to come, becomes highly important to the operator. Although the line of reasoning is applicable to the various units, let us take the engine alone, largely because it is the most expensive single item in the chassis, first considering the assembled truck.

With a view to making available as wide a selection as possible, a study was made some time ago which resulted in the establishment of a classification of trucks according to their weight-carrying capacities, and in a distribution within the respective classes of as many different makes of chassis as seemed to offer promise of reliable interchangeability of units.

In the course of this study we found that in one class of four makes which appeared to have the same units, three did have interchangeable engines; but the manufacturer of the fourth, for some reason best known to himself, had prevailed upon the engine builder to modify the dimensions of the supporting arms so that the distance between supporting bolts differed by about 1 in. on that model from the distance that prevailed in the other three. Manifestly, this might just as well have been an engine of entirely different design, as it was impossible for the prospective purchaser to plan on a spare unit that might be used interchangeably on this truck and on the three others. The result was the elimination of any consideration of this particular truck from the classification that was developed. This elimination cast no reflection on the merits of the design of the truck. No reason existed for thinking that it was in any way inferior to the three others but, from the standpoint of the purchaser, the only possible thing to do was to rule it out of consideration.

If the manufacturer of trucks, as distinguished from the assembler, and particularly the producer of trucks of long potential life, is to look forward to favorable consideration by the operator whose use of trucks necessitates a comparatively short mileage-life and hence early obsolescence, he apparently must incorporate provision in his truck that will enable the purchaser to modernize that truck in due time without a disproportionate outlay for the unit of later design. Without attempting to go into all of the ramifications of the problem, and at the same time not forgetting that the following illustration may be a somewhat crude one, let us consider the present period of transition from the four to the six-cylinder engine.

Many of us today are operating trucks that are fitted with four-cylinder engines, but which, with this exception, might easily be stepped up to meet the present-day demands, particularly with reference to speed. Would it have been impossible for the manufacturer of this particular engine to have adopted essential dimensions for his four-cylinder engine which would have permitted its replacement with a present-day six-cylinder engine without further change in the chassis? And what of the future, the eight versus the six-cylinder engine?

I am now operating a number of trucks powered with four-cylinder engines and originally equipped with solid

tires, which were designed to operate at a maximum speed of 12 to 15 or possibly 16 m.p.h. These trucks are still good for many thousands of miles, and a year or two ago a number of them were converted to use pneumatic tires. To do this required a substantial expenditure that resulted only in a stepping up the speed capacity to 20 to 22 m.p.h. Long and exhaustive study was necessary to determine that such an expenditure might be justified. It will be recognized that the increase in speed was limited particularly by the engine capacity. On the other hand, considerations of capital requirements finally dictated a program of conversion to pneumatic tires rather than complete replacement. Hence we are using today a number of trucks that, speaking broadly, are capable, except for the engine, of operating at speeds commensurate with prevailing practice; but, since we cannot modernize the engine and because of the necessity for conservation of capital, we continue to operate a larger number of trucks than would be required with faster equipment. We, as operators, would more readily accept the claims of the manufacturer for long life of those trucks if we could be assured that pure obsolescence would not be likely to dictate their comparatively early retirement.

Reduction in Chassis Weight

Undoubtedly many operators continue to give little thought to the weights that should be imposed on the chassis in the form of bodies and mountings, but there are evidences that serious thought has been given to this phase of their problem by the larger-scale fleet-operators. To cite a single instance in our own experience which applies only to trucks ranging between 2 and 3-ton capacity as commonly rated, we have reduced this unproductive weight by 800 to 1000 lb. and I consider that we have not yet reached the limit. However, we continue to find that the chassis weight remains at a high level. That the truck manufacturer should be able to make a substantial contribution in this particular direction seems apparent to the operator.

Mention was made of the apparent unimportance of realizing interchangeability of units as between trucks of different carrying capacities. I believe that in this one item alone a substantial improvement might be made by the manufacturer. At present, one size of rear axle and its assembly frequently is used in trucks of two or more different weight-carrying capacities. As a result, a truck of light rating often carries a considerable additional dead weight as compared with one of heavier rating. This probably means to the manufacturer a smaller range of products and of stock than would be necessary if the truck were designed for a narrower range of capacity and its use limited to a single rating. On the other hand, the manufacturer is faced by the competitor who undertakes to assure the operator that a chassis which is much lighter is capable of carrying the load that the first manufacturer recommends for his chassis. The competitor predicates his higher-load recommendation on the substitution of a heavier unit, perhaps only for the rear end. As a result, the unthinking operator will select the lighter chassis, with the heavier single unit, and quite possibly one or two or three years may elapse before he realizes that he is overloading the remainder of the truck and, in doing so, is paying the cost of premature retirement. The solution, or even the improvement, of this condition admittedly rests largely upon a program of education. Probably the responsibility for such educational work will devolve largely upon the manufacturer, although the live operator may make a substantial contribution.

Another aspect of this question of chassis weight with which the manufacturer is believed to be vitally concerned, and in which he may easily render a genuine service to the operator, is the question of legal restrictions having to do with speeds and particularly with weights of vehicles on highways. Probably all will agree that at present, and as between different States, this whole question is in a very badly muddled condition. If those who are responsible for the development of our legislation and for the care and maintenance of our highways will recognize that the simple factors of speed or weight are of comparatively little importance in themselves, but that they are particularly concerned with the product of the two, we shall be able to clarify the whole situation to a considerable degree. The truck manufacturer should be able to clarify his own problem of chassis design. Some time ago much advertising capital was made of the unsprung weight of their design by the manufacturers of passenger-cars. All of this publicity, however, had to do with the effect of the unsprung weight on the riding-qualities of the car. The truck manufacturer should be concerned with the reverse effect; that is, with the effect of unsprung weight on the impact on the road.

I do not purpose to enter into a discussion of the question of unsprung weight. In fact, this does not seem to constitute the whole problem. If we accept the view that impact on the road should be the consideration which ultimately governs the various legal restrictions which may be imposed on the operation of trucks we find that, on a given type of highway construction, a constant impact becomes permissible and the operator may with comparative ease determine the relationship between weight and speed that will be most advantageous for his particular operations. Similarly, should the operator have occasion to move a given weight over highways that are capable of withstanding differing impact values, he may control that impact through the medium of the speed of the truck. Then there is the question of the type of tire. The impact on the road is vastly different for a given weight as between trucks equipped with solid and balloon tires.

If the manufacturer of the truck will approach this problem of design with a view to reducing the impact on the road to the lowest possible point, he will consider not only unsprung weight but the spring design and the weight imposed on the springs. He may, for example, seek to attain the minimum of impact by starting his design with the use of solid tires. If this be done, he will be in a vastly improved position as he progresses to the use of the high-pressure and low-pressure pneumatic tires. Manifestly, the latter will produce the minimum of impact as between the various types of tire.

Uniformity of Frame Dimensions

A fairly full discussion of this topic was held among representatives of operators and manufacturers at the meeting of the American Petroleum Institute in Chicago in the early part of November, 1930. It seems unnecessary, therefore, at this time, to do more than briefly outline the major points of that discussion.

In the determination of types and design of mounting and the distribution of loads we are more concerned, as

operators, with the length from the back of the cab to the center of the rear axle and to the rear end of the frame than we are with the wheelbase. Up to the present, the manufacturers have been disposed to group their several classes of equipment according to wheelbase and to subordinate the dimension from the back of the cab to the center of the rear axle. The fact seems to have been brought out rather clearly, during the 1930 discussion referred to, that this matter of wheelbase is of secondary importance from the viewpoint of the operator. In that discussion one operator presented a chart showing that he has adopted a certain type of mounting which is predicated upon a definite distance from the back of the cab to the center of the rear axle. Allowance is made for a certain variation in this dimension, but the fact was pointed out that those trucks in which this dimension varied beyond a certain maximum were virtually, of necessity, ruled out of his consideration. Another point made clear was that the operator is not concerned with having a fixed dimension in this respect and, further, that he does not think that any chassis must be built specially for his purpose. The problem is rather that of having a known variation and of having this uniform as between the different makes of truck.

As operators engaged in the oil industry, we are of the opinion that increments of 6 in. on smaller trucks and 12 in. on larger trucks, as representing the varying dimensions on a given chassis from the cab back to the rear-axle center, will be adequate to meet our needs. We are inclined to think that increments of this size should be adequate for many other operators as well, but we realize that the manufacturers' experience may indicate the necessity for smaller increments to meet the demands in the varying fields in which they are working. As an operator, I see no objection to smaller increments; we recommend the larger values out of consideration for the manufacturer. They should simplify his problem of supplying the substitute parts that will be involved in the variations of wheelbase or, more specifically, of the space from the cab to the rear-axle center.

It does seem that the different truck manufacturers should be able to agree upon the adoption of a definite scale of variable dimensions for the several sizes of chassis they may produce. I believe that some movement is already under way in this direction, and also to make provision for uniformity as to the width of frame on various chassis; so we have reason to hope for some fairly early contribution toward improvement of this particular condition. The importance of uniformity in both length and width will be more apparent if the fact be borne in mind that a single mounting may easily outlive two and three chassis.

Comparable Cost-Accounting System

In concluding this discussion, I desire to comment briefly on a subject of particular concern to the operators of fleets but which manufacturers will recognize as being of distinct interest to them as well.

For a considerable time past much discussion, both oral and written, has been devoted to the difficulties of developing a workable basis upon which to establish costs that may be comparable as between different industries and enterprises. That this question is generally conceded to be an extremely difficult one has been evident for a long time. As I have continued to study the problems of the particular fleet with which I am engaged and have discussed the same problems with operators of other fleets, I have become more and more convinced that the greatest part of the difficulty that has been encountered in this whole field has been due to the fact that we have subordinated one important intermediate step in our effort to arrive at the final figure which, perhaps, is of ultimate interest to us as individuals. I refer to the tendency, and to what appears to be the prevailing practice, to reduce the expense of the operation of automotive equipment directly to terms of the cost of distribution of the unit. This may be in terms of cents per pound, per gallon, per quart, per package, per ton, or whatever unit may be applicable to the particular activity. The result is that we completely obscure the features and factors that should enable us to give an intelligent study of, and supervision over, the use of the automotive equipment.

If we will recognize that we are dealing with an instrument of the basic field of transportation, that our unit of measurement should be the distance traveled should become evident. This must be subdivided according to the size or load-carrying capacity of the equipment, but when such subdivision is made we may reasonably rely with full confidence on the mile as a unit of measurement. In effect, this amounts to using the ton-mile of *carrying capacity*, not of weight carried. Another important point is that, while undoubtedly the maintenance of a detailed record of the experience with each piece of equipment is of vital importance, relying upon averages over a long period, and preferably over a large number of vehicles, is of equal importance for determining the transportation cost that must enter into our problem of distribution. After we shall have come to recognize the value of this intermediate step in determining transportation costs, we shall find ourselves in position to make fairly intelligent comparison at practically any time with any other operator, not only of the expense of operating automotive equipment, but also of the expense of distribution. And what we shall find to be of only slightly less importance will be our ability to say to the manufacturers of trucks that our experience tells us that we shall require certain things of their products in the future in a way that will be convincing to them and hence will enable us to realize fairly effective teamwork between the producer and the user of automotive equipment.

THE DISCUSSION

A. W. SCARRATT[2]:—Referring to the transportation group of the Society, we are now organizing to consider how to bring about uniform dimensions in frames, such as the length of the frame from the back of the cab to the center of the rear axle and the width of the frame, so that the manufacturers of all kinds of special-body equipment can produce standardized units fitting any one of several different makes of chassis without need for alteration. Thus their business will be on a better production basis, their equipment can be manufactured at lower cost, and the operators can purchase for a lower price.

Interchangeability of units in a large fleet is highly desirable, but it has not been accomplished to any great

[2] M.S.A.E.—Chief engineer, motor-truck and motorcoaches, International Harvester Co., Chicago.

extent between competitive makes of truck. Naturally, in fleet operation of say 750 trucks, interchangeability of the major units is of great help in keeping the vehicles on the road for the maximum time. However, concerning the major units of chassis which are the production of large-scale motor-truck manufacturers and which are distinctive units, I doubt that much interchangeability is possible between chassis of that type and chassis of the assembled type.

In the long run extensive alterations that amount to rejuvenation of old-type vehicles probably will not pay. One hardly knows where to begin and, after beginning, one hardly knows where to stop. If a six-cylinder engine is installed in a vehicle originally equipped with a four-cylinder engine, this is likely to necessitate extensive alteration in the forward part of the chassis. Probably the chassis will not be long enough to accommodate the six-cylinder engine. Changes must be made in the cooling system, water connections, engine and transmission connections, fuel piping, wiring and the like. If increased speed and flexibility of operation constitute the objective, the six-cylinder engine is the more-powerful unit. Then the question arises whether the transmission will be adequate. Gear changes will be necessitated and finally, changes of wheels, tires and brakes. We should remember also that to install modern brakes on old equipment is not easy.

A. W. SCARRATT

The cost of truck operation is a subject that can be attacked from many angles. Trucks are sold to such a variety of operators that cost becomes a very involved subject when depreciation, obsolescence and all the essential kindred factors are included. If all truck operators would realize that when the truck is designed it has a safe limit of capacity for a reasonable length of life and reasonable maintenance cost, most trucks would do much better work at a lessened operating cost.

The desire for reduction of dead weight of chassis is a logical objective. How this can be done while still satisfying the existing curse of extreme overloading is a difficult problem. We find that the demand actually faces us to increase the strength of all the major units of a given chassis, so as to try to keep pace with the abusive treatment the chassis receives rather than to be enabled to reduce its weight.

Factors of Present Problems Stated

B. B. BACHMAN[a]: Regarding the attainment of greater sustained speed rather than increased maximum speed, obviously the rational way to increase operating ability without incurring the penalties of increased maintenance cost, increased risks on the highway and the like is in just that manner. But increased sustained speed introduces a train of conflicting requirements for the manufacturers. For example, it assumes a larger powerplant, which means a lower powerplant load-factor. That is one of the major difficulties that we face at present in trying to obtain satisfactory operating costs. In regard to reduction in chassis weight, Mr. Scarratt's comments are exactly in line with our own experience.

[a] M.S.A.E.—Vice-president of engineering, Autocar Co., Ardmore, Pa.

Within the elastic limit, when the deformations are proportional to the stresses, the modulus of elasticity is constant for all ferrous materials; but beyond the elastic limit it decreases rapidly. If some genius discovers a method of alloying that will change the modulus of elasticity, we will then be enabled to answer this question of weight reduction. At present, the increased impact forces which are produced by increased speeds have produced conditions that have made it necessary to stiffen many parts of the vehicle, such as the frame. Although vehicles are operating on pneumatic tires, they are operating at much greater speeds. For such speeds, brakes have been installed which will control the vehicles more quickly. This increases the rates of deceleration as well, having a greater effect on causing chassis deflection. This has necessitated stiffening the frame, which makes the frames heavier.

Aluminum might be used for some parts that are at present made of cast iron. Do operators have any definite information as to how much weight reduction is worth to them per pound in operating costs? Weight reduction by using lighter materials is conceivable, but the vehicle cost will increase more rapidly than the weight reduction is effected. If the vehicle cost is increased and that increase is passed on to the buyer, can he earn a fair return on that increased investment? If so, how soon?

Regarding the author's plea for a projection of our present knowledge into the future so that we can design vehicles which will be suited to the adaptation of improved equipment at a future period, I cannot in any way agree. He illustrates his point by mentioning interchangeability in connection with substituting a six-cylinder for a four-cylinder engine on the same chassis. He even suggests an eight-cylinder engine as a possibility for such purpose. But I shall take no measures at present to attempt to say what future engine development may be.

Concerning regulation, the author pleads for the recognition of the product of speed and weight as being the consideration upon which restriction should be based. This seems to me a difficult matter for the State highway departments to control. Essentially, in their case, the necessity is for some factor that can be readily ascertained by the men to whom the detail of enforcement is entrusted. To develop a complex condition of this sort seems to me wholly impossible, but that in nowise disputes the accuracy of his conclusion that this is one of the major controlling factors.

Mr. Bennett states that

> Similarly, should the operator have occasion to move a given weight over highways that are capable of withstanding different impact values, he may control that impact through the medium of the speed of the truck.

In my opinion the use of the word "may" is the crux of the situation. The operator *may*, but *will* he? That is the reason for laws.

On the subject of uniformity of frame dimensions, that result should be obtained readily. Manufacturers have been somewhat remiss in having allowed wheelbase length to become the dimension most frequently used in our literature and discussion. Unquestionably,

the loading space, that is, the distance from the back of the cab to the center of the rear axle, is *the* dimension which essentially governs; the reason is that this is the dimension which the body builder must use. That uniformity of the dimension may be attained seems to me entirely possible. Whether establishing a line of dimensions that will be applicable equally to different industries will be found possible is a question which should in nowise interfere with the establishment of this dimension for an important industry. If other industries of equal importance cannot accommodate their requirements to the dimensions that are thus selected, I fear that no other solution is possible than for the manufacturers of trucks to meet that situation, even to the extent of building more than one line of chassis, and they are building enough different lines of chassis now.

Changing Conditions Affect Design

L. R. BUCKENDALE[4]:—I was impressed with the open-mindedness of Mr. Bennett's paper but think it hardly fair on his part to dissect the modern motor-truck with the expectation that the designers should have foreseen the changes that have occurred in the last five years and should have made the truck of the earlier period of such design that the improvements which have since been made could have been incorporated when the truck was built. For example, the recent changes in truck design include four-wheel brakes; changes in the axle equipment and in the hookup of the braking system necessitated by four-wheel brakes; a change from solid tires to pneumatic high-pressure tires both single and dual; and the introduction of the low-pressure balloon-tires.

Coincident with the changes enumerated, the highways have changed greatly. If we had attempted to market a truck having a 96-in. over-all width or more for use on the highways say nine years ago, the cry would have been that the truck was taking up all of the road. Today we have super-highways and, even then, we are crowding the legal restrictions on over-all widths. The low-pressure tire necessitated changing the axles to obtain correct load-distribution, because the low-pressure tire assumes much of the available over-all width of the vehicle; it is today ruling out the wide frame that formerly existed on many trucks. The frame, formerly, was 32 to 42 in. wide. Today, we can just begin to see a possible standardization in frame widths because the legal restriction and the low-pressure tire have forced all manufacturers into a certain narrow range which is making possible some standardization on frame widths.

A. J. SCAIFE

Design for Short and for Long Mileage

G. P. ANDERSON[5]:—One phase of Mr. Bennett's paper interested me particularly; that is, his grouping of operators into (*a*) those engaged in professional hauling and whose vehicles operate for a relatively high mileage during a five-year period of life and (*b*) those whose vehicles are rather incidental to their principal business and whose mileage is therefore relatively less. If only we could ask our engineers to design to a definite mileage and to construct the vehicle so that at the end of say 100,000 miles it would, like the "wonderful one-hoss shay," be ready to drop apart all at once and yet up to that time be sufficiently good to operate economically, that would be fine; but it is not possible. Further, economy of manufacture and quantity production make necessary the adherence to definite standards in construction which will give efficient operation over the greater maximum-mileage period for which the design is contemplated.

Even though it were possible from an engineering standpoint and one were to attempt to reach the first design-goal outlined, having one line for shorter mileages and another line for longer mileages, it would introduce expense in manufacture that would tend to prevent the purchase of both lines. The best economy for the limited-mileage operation is obtained by a type of design which will give economy for the longer period, considering that the parts which wear are readily replaceable and that it is not a case of reconstructing the truck to obtain the long mileage-life.

Mr. Bennett's conception of the basis for cost determination is very sound, and I believe it is broadly recognized. In fact, I know of no instance in which the ton-mile has been very long adhered to as a cost basis.

CHAIRMAN A. J. SCAIFE[6]:—What is the trend and what do the operators have in mind with reference to the kind of operation suited to the types of vehicles used on the Pacific Coast?

E. C. WOOD[7]:—For inter-State usage in California, Arizona, Oregon and Washington, the trend is to use the six-wheel truck and the six-wheel trailer and to carry 34,000 lb. Pacific Coast operators feel that the foregoing load on the two six-wheel vehicles is economical.

H. B. HEWITT[8]:—I would like to support Mr. Bennett on the subject of anticipating what the requirements of design may be a few years hence. I suggest that, in developing larger engines or different equipment, the designers might consider the millions of dollars invested in trucks that cannot economically be charged off the books and develop improved equipment to fit into some of the older vehicles, thereby providing an outlet for their parts departments which might otherwise be taken advantage of by a competitor or some engine manufacturer.

In one instance in which a manufacturer developed a large engine, by using adapters, some of the motorcoach operators can install that engine in the older equipment. In another, one or two axle manufacturers have made possible the installation of improved differentials in the axles. We are operating more than 100 trucks and have been faced with the same problem that other truck operators have in regard to increasing the loads and the speeds. In the way outlined, I believe that we might make more progress and provide a market that would not exist otherwise.

[4] M.S.A.E.—Executive engineer, Timken-Detroit Axle Co., Detroit.

[5] M.S.A.E.—Director of sales engineering, Chrysler Corp., Detroit.

[6] M.S.A.E.—Consulting field engineer, White Motor Co., Cleveland.

[7] M.S.A.E.—Division superintendent of transportation, shops and buildings, Pacific Gas & Electric Co., San Francisco.

[8] Engineering assistant to vice-president of operation, Mitten Management, Inc., Philadelphia.

Legislative Trends Unfavorable

PIERRE SCHON[9]:—Since I presented my 1930 Annual meeting paper on Weight and Size Trends in Motor-Truck Development[10], I have devoted much attention and time to that subject. Legal restrictions and regulations are threatening to become more stringent by imposing unreasonable limitations on sizes and weights of commercial vehicles, thereby affecting design as well as operation. With more than 40 legislatures in session, manufacturers are asked for contributions to State associations of truck and motorcoach owners to assist them in their efforts to protect the interests of commercial transportation. In some States radical changes are pending to reduce maximum weights and vehicle lengths, not to mention the attempts that are being made in almost every legislature to raise taxes, especially on the larger sizes of truck and motorcoach.

PIERRE SCHON

I call attention to the need of watching carefully what is going on in the State legislatures. Attempts are being made to reduce the earning capacity of commercial vehicles, which can be done very easily by reducing maximum axle-weight or maximum vehicle-weight, and by reducing length, height and width. It is really a deplorable situation, and nothing but coordinated efforts on the part of the manufacturers and the operators can forestall some very drastic legislation during 1931.

In handling this situation the groundwork must be done with the highway-engineering department of the manufacturer's and the operator's individual State, especially where sizes and weights are concerned. Due to propaganda against trucks and motorcoaches, any bill to increase vehicle-weight or increase vehicle-sizes hardly will be passed by a State legislature, unless such changes have been approved by the State's highway engineers. In fact, the lobbying interests intend to reduce motor-vehicle weights and sizes, and no need exists to hide the fact that passenger-car owners are supporting those measures because they feel that the trucks and motorcoaches are taking up too much space on the highways.

Any reduction in vehicle or in axle weights will increase the cost per ton-mile of merchandise that is hauled on a motor-truck; any increase will have a tendency to decrease that cost per ton-mile. Except in a few States, no effort has been made by State legislatures to differentiate in weight regulation between pneumatic and solid tires. Most of the laws relating to weight are based on vehicles equipped with solid tires, and very little credit has been given to balloon tires for the enormous reduction of impact on the pavements and on bridge structures which they have effected.

Some changes have been proposed in the Michigan laws relating to weight. After presenting facts and figures to our Michigan highway-engineers, we succeeded in enlisting their aid and approval in formulating amendments to Michigan's present motor-vehicle laws along lines of sound and practical limitations. In dealing with State legislation on sizes and weights, manufacturers and operators first should consult with the highway engineers of the State. Support Act No. 4 of the revised Hoover Code as set up by the National Conference on Street and Highway Safety, advocate the classification of highways and, above all, recommend the allowance of greater weight for vehicles equipped with pneumatic tires. State highway engineers are opposed to heavy weights on solid tires, and very little chance exists to increase axle-weight limitations unless a difference of at least 20 per cent in weight is established in favor of the pneumatic-tired vehicle.

The subject of legal regulations of sizes and weights of motor-vehicles constitutes a very serious problem during 1931, because so many State legislatures are in session. Some very drastic legislation is pending in several of the Southern States and, if some of these radical bills become laws, the larger motorcoaches and trucks will have very little chance to be operated legally below the Mason and Dixon Line in the future.

CHAIRMAN SCAIFE:—Passenger-car owners are not entirely immune from this attack on motor-vehicles by the railroads. One railroad has an article on the back of its dining-car-service menu calling attention to the dangers to which passenger-car operators subject themselves when they drive long distances such as from New York City to Florida, instead of buying five railroad tickets that entitle two passengers and a car to be transported by rail. They try to frighten owner drivers regarding holdups and the terribly bad conditions of operating on the highways because of these great big trucks and motorcoaches that force cars into the ditch and kill the occupants. Evidently, the railroads have their guns aimed at the entire automotive industry. They are trying in this way to increase business with reference to passengers as well as to freight.

J. B. WALKER[11]:—We might console Mr. Bennett with the idea that invariably when an engineering department has some new development in mind, such as a six-cylinder engine to be installed in an existing four-cylinder truck, the sales department manages somehow to hear about it and to secure an order for it. In other words, Mr. Bennett may feel assured that he has not missed anything, because the sales department would have sold it to him even if it was only on paper.

[9] M.S.A.E.—Sales engineer, General Motors Truck Co., Pontiac, Mich.

[10] See S.A.E. JOURNAL, August, 1930, p. 187.

[11] Engineer of special equipment, Mack International Motor Truck Corp., New York City.

Leakage Tests of Piston-Rings

TWO methods of testing piston-rings for leakage have been practised at the plant of the American Hammered Piston Ring Co., one a static test and the other conducted under working conditions. The two methods used are described in the following, which is abstracted from a paper presented by A. Preston Petre, experimental engineer of the company, at a recent meeting of the Washington Section. Results of both types of test on piston-rings of different designs are given in Table 1, herewith, which includes diagrams of rings of the various types.

The static type of test is conducted in a head-down cylinder in which the piston is inserted and prevented from blowing out at the upper end by an air-tight hood and push-rod. Compressed air is introduced below the piston-head through an inlet provided with gages and an equalizing valve which prevents inaccuracies in the tests from fluctuation in the line pressure. The test is controlled entirely through a single hand-lever, which admits the compressed air, operates the timer and releases the pressure.

Leakage is measured by means of a low-reading gas-meter which is connected to the hood and records the loss in cubic feet. In the tests recorded in Table 1, air was admitted to the cylinder at a pressure of 80 lb. per sq. in. for two 15-min. periods, and the amounts of air which the rings permitted to pass were recorded and averaged. All rings tested had the same end-clearance and were lapped to a perfect bearing in the cylinder. No lubricant was used during the tests. The total diametral clearance between the piston and the cylinder was 0.010 in.

Tests Under Working Conditions

A Bauers 5-hp. single-cylinder marine engine having a bore of 5 in. and a stroke of 7 in. was used for the working tests. The piston is fitted with two ¼-in. compression rings and one oil-control ring, all of the individually cast type, hammered for tension, inspected for diameter and flatness and subjected to a light test for roundness. The average of Rockwell hardness tests on various rings ranged from 96 to 102.5 on the B scale. The tests were conducted to measure the leakage of the cylinder compression through the joints and piston-rings of various designs. No effort was made to record other characteristics of engine performance, though conditions were held constant for each test.

The crankcase was sealed and connected through a tube and check-valve to a gas-meter of standard design to determine the leakage loss in cubic feet per minute. The engine was started cold and run for 2 hr. without load at 250 r.p.m. At the end of this time the engine speed was raised to 400 r.p.m., a brake load equivalent to 4 hp. was applied for 10 min. and the leakage carefully noted. After this the piston was removed and the rings were lapped to a perfect seat, not being removed from the piston to avoid possibility of distortion in springing them over the piston.

After lapping, the same tests were repeated and the results compared. In each case the absolute leakage was less on the final test than on the preliminary test, but the two tests checked in regard to relative leakage of the various designs. The figures given for these tests in Table 1 are the averages from the preliminary and final tests.

It must be noted that the running-test results recorded in Table 1 are applicable only to low speed and are merely comparative. The time interval for leakage and the speed at which a ring fails entirely to function must be given serious consideration for engines of higher compression and higher speed.

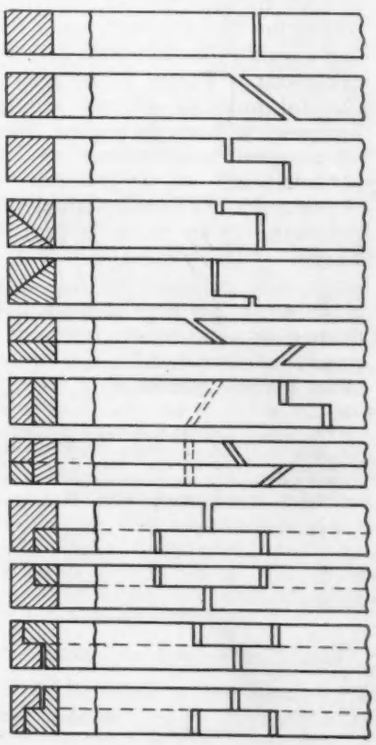
Two single-cylinder Diesel engines were used in a most interesting piston-ring test which was carried out in Scotland. One of the engines was running and was connected through a pipe to the combustion-chamber of another engine of the same size, in which the piston was blocked at top dead-center. Indicators were installed at various points, one in the working cylinder and others behind each ring and between each two rings of the blocked piston. The maximum pressure recorded in the cylinder and the average pressures at the other points, in pounds per square inch, were as follows:

Cylinder pressure	580	Behind second ring	115
Behind first ring	440	Between second and third	55
Between first and second	115	Behind third ring	45

Audible blow-by to the crankcase of an engine is almost always due to fitting the top ring too tightly in its groove. It should always be allowed enough side-clearance to function, in view of its difficult position in relation to pressure, temperature and lack of lubrication.

TABLE 1—RESULTS OF LEAKAGE TESTS OF PISTON-RINGS

	Cubic Feet per Minute	
	Static	Running
Straight	2.00	0.55
Angle	2.13	0.53
Step	1.50	0.50
Step Seal	0.70	0.40
Step Seal (Reversed)	0.90	0.43
Plain, double	2.16	0.46
Two-Piece Compressor	...	0.44
Three-Piece Compressor	1.06	0.39
Inner Seal	2.60	0.36
Inner Seal (Reversed)	1.38	0.45
Two-Piece Seal	1.17	0.36
Two-Piece Seal (Reversed)	2.56	0.41



Breakage of piston-rings can frequently be traced to allowing insufficient end-clearance. The piston and rings heat more rapidly than the cylinder, when the engine is started, causing the rings to expand and sometimes to jam.

Causes of Piston-Ring Breakage

Destruction of the piston-rings apparently is caused in some exceedingly high-speed engines by ring fluttering, although the speed of the ordinary automotive engine is not sufficient to cause this difficulty. The fluttering becomes apparent both audibly and visually, on the test stand, by an appreciable clatter from the crankcase and considerable clouds of oil-vapor under pressure issuing from the breather. When this phenomenon is experienced on the road, it is usually accompanied by abnormally high oil-consumption, and the entire engine compartment is likely to be surrounded with oil and oil fog.

Another cause of ring breakage is worn cylinders resulting in loose piston fits. This condition allows the piston to hammer the ring against the cylinder enough to cause fracture. As the piston-ring rotates in its groove, the joint at some time comes in line with the piston-pin. This subjects the sides of the ring, 90 deg. away from the joint, to the maximum side-trust, thus shaking the ring to the point where its vibration period may be reached. Under these conditions, the ends of the ring, which are usually weaker than the rest of the body, may be shaken off. This theory is borne out by the fact that fractures of this type always appear first at a short distance from the joint of the ring and, as far as we have been able to ascertain, always in line with the piston-pin.

A Survey of Mobile-Type Diesel Engines

Additional Discussion of C. G. A. Rosen's Annual Meeting Paper[1]

C. G. A. ROSEN:—Mr. Vincent states that I claim "that recent progress due to fundamental research has resulted in our activities." He objects to my use of the term "recent" in connection with Diesel-engine progress.

My statement was: "The development of fundamentals associated with high-speed Diesel engines has been responsible, to a great extent, for the recent substantial progress in large solid-injection Diesel engines." No one questions that the marine Diesel has accelerated in activity; Lloyd's reports are too conclusive in this respect. To anyone who has followed oil-engine development for a number of years, a passing casual reflection may give voice to the oft repeated cynicism: "There is nothing new under the sun." Careful analysis of any single line of development, however, will surely reveal the fact that the progress of research ever moves on to newer milestones of achievement.

Certainly the accomplishments of Sulzer Brothers in producing their latest large solid-injection Diesel are worthy of commendation. The many years of valuable experience gathered by this company was essential as a basis for this development, but who can deny the influence of combustion research in consummating this recent achievement? The Sulzer Bulletins have too often given expression to the high type of combustion investigation conducted by the organization for anyone to doubt this statement.

The A. E. G. Hesselman double-acting Diesel, a comparatively recent product, is undoubtedly a reflection of research activities. The results obtained in the spray-research laboratory of Dr. Sass and the patient experiments and investigations of Hesselman cannot be divorced from this accomplishment.

The Doxford organization, after years of engine building, reduced the fuel consumption of its large Diesels from 0.41 lb. to 0.36 lb. per b.hp-hr. as a result of combustion research.

These are but a few instances selected at random from actual installations. Recent noteworthy contributions that are beyond the scope of this paper have also been made by M. A. N., Burmeister & Wain, Krupp and others, all of which bring predonderant evidence to justify the questioned statement and further enhance the economic value of research conducted on the combustion process and its related elements.

Although the developments in large engines have continued through the years, the accurate determination and measurement of functional values concerned with combustion conditions and their control have come to the fore only with the urgent need for high-speed-Diesel research data. That this activity is recent is further attested by the increasing demand for a closer correlation of experimental results with design factors.

The spark-ignition type of oil engine was never regarded as a Diesel unit; it was appended to the list simply to complete the classification of oil-engine types.

[1] The paper and discussion were published in the S.A.E. JOURNAL for March, 1931, p. 301. The author is Diesel engineer of the Caterpillar Tractor Co., San Leandro, Calif. The reply of the author to the discussion was received too late to be printed with the paper and is published herewith.

Standardization Progress

Airplane Landing-Lights

Summary of Tests Made by Army Air Corps for S. A. E. Aircraft Lighting Committee

THE Aircraft Lighting Committee, appointed by the Aircraft Division of the Society's Standards Committee soon after its formation, searched the records of the industry for data as to the fundamental requisites for airplane landing-lights that would be suitable for making landings on dark, strange fields. No data were found to exist and the opinion of pilots and lighting-equipment manufacturers varied greatly, often mainly due to experience with one particular equipment.

It was obvious that a systematic study should be made of the results to be desired, these results to be expressed in terms of beam candlepower at various angles ahead of the airplane. This would make it relatively simple for the device manufacturers to design equipment to meet these requirements. Therefore the Committee, with the cooperation of manufacturers, assembled test equipment including batteries, generators, landing-lights, lamps and lenses which would make possible the production of light beams of various sizes, shapes and intensities. Sets of the test equipment, together with instruction sheets for conducting the tests and recording the data, were furnished to several operating companies and to the Army Air Corps.

Work Done by Army Air Corps

Because of pressure of business, the operating companies were unable to carry out their agreement to determine by service tests the most suitable light patterns for landing under various conditions. No reports were received and no constructive work was done except by the Army Air Corps at Wright Field. The Society is grateful for the excellent work of Lieutenant D. L. Bruner and Major A. H. Gilkeson. The long experience of these Air Corps officers makes their conclusions of great interest. Unfortunately, an equally comprehensive report by an organized transport company does not exist to indicate whether the lighting on commercial airplanes should differ from that for military aircraft.

At Wright Field, Dayton, Ohio, under the direction of Major Gilkeson and Lieutenant Bruner, an airplane was equipped with three landing-light units—a reference unit and two test units. Landings were made with various combinations of lenses and reflectors, and the pilot's opinion noted in each case. In addition, light-distribution curves were obtained on the various combinations, so that a permanent record of the test is available.

High Beam-Candlepower Desirable

Of the conclusions, perhaps the most noteworthy was the importance placed on high beam-candlepower, or long range of light penetration. Desirable maximum beam-intensities were of the order of 10 to 20 times those used in automobile headlighting practice. The reason is not difficult to see, when the higher speeds and extreme need for accurate judgment of altitude are considered.

Horizontal Spread of Beam

A horizontal spread of beam was found to give a desirable ground perspective and might be recommended, except that as the light was spread more and more sideways the maximum candlepower decreased rapidly. With

ARRANGEMENT OF LANDING-LIGHT TEST UNITS USED IN THE ARMY TESTS—BOMBARDMENT TYPE AIRPLANE

sufficient candlepower, a horizontal spread of at least 20 deg., produced by a 12-deg.-spread lens plus the inherent spread of the unit without lens, would be useful. This checks generally with the findings of various European investigators.

Two Units Giving Dissimilar Beams Are Not Recommended

From the foregoing it might seem that two units of different type would be desirable, one with a high beam-candlepower for distance observation and the other with a wider horizontal spread. Army engineers reported that this was desirable when both units were operating, but is not necessarily to be recommended in service, because a burn-out of the high-intensity narrow beam, for example, would leave the pilot without long-range light, or vice versa. They conclude, therefore, that with the present types of equipment it is safer to provide two narrow high-intensity beams rather than one narrow beam and one with a wide spread.

Perhaps the solution is to use high-wattage lamps, with larger reflectors, so that each unit can produce the desired beam distribution, as with the automobile headlight. Then a failure of one unit would mean merely a diminution of intensity instead of a radical change in beam distribution. It is not difficult to produce almost any desired beam pattern. This might consist of a relatively narrow part of extremely high intensity at the top of the beam, and, to each side and possibly slightly below, a somewhat lower intensity spread out to about 20 deg.

Vertical Beam Spread

To facilitate landings, the Army report indicates that it is desirable to have the *lower* cut-off of the beam strike the ground at about the same point ahead for all planes, which in itself helps give the pilot some idea of height above ground just prior to setting down. This, to be effective and useful, would mean a fairly sharp cut-off at the lower edge of the beam and a careful setting on the plane, dependent upon the height of mounting above ground, or a vertical spread of beam selected particularly for the mounting height on the plane.

Because of the failure of the operating companies to cooperate in obtaining test data, the Aircraft Lighting Committee has recalled the test equipments. It appears that further fundamental data will have to be collected bit by bit as a result of experience until it becomes feasible for someone to undertake further systematic study. Meanwhile the Committee will continue, having been expanded to include other electrical features of the airplane in addition to lighting. It will operate as a forum where problems, ideas and solutions can be discussed.

Comments by Lieutenant Bruner

With reference to the Summary of Landing-Light Tests, Lieutenant Bruner makes the following comments:

It is undoubtedly true that very little information is in the records of the industry regarding aircraft-lighting requirements, as the industry did not do the pioneer work which determined the fundamental requirements. The Air Corps's cooperation in the endeavor of the Society to investigate the fundamental requirements of aircraft landing-lights was given in the hope that the manufacturers would benefit by it and that the Air Corps might benefit indirectly by securing more nearly satisfactory equipment. The tests outlined by the S.A.E. and conducted by the Air Corps were not by any means complete, hence it is desired to bring the following points to attention:

High Beam-Candlepower Desirable.—High beam-candlepower is desirable to a certain extent, that is, a beam-candlepower of 300,000 is better than a beam candlepower of 100,000; however, beam candlepowers higher than, say, 500,000 are undesirable and the worse the weather is, the more undesirable an extremely high candlepower becomes. A landing-light with 2,000,000 or 3,000,000 cp. in the beam is quite useless, while, in good weather, a landing-light of only 50,000 beam cp. may be entirely satisfactory. In general, for all-round use in all kinds of weather, it is as important to avoid stray light and have a sharp cut-off at the edge of the beam as it is to have a tremendous beam-candlepower.

Horizontal Spread of Beam.—If horizontal spread of beam up to a maximum of 20 deg. can be readily obtained without stray light and with an extremely sharp cut-off at the edge of the beam, it will be found advantageous in good weather. In bad weather, however, there will be increased reflection from moisture in the air and the advantage will be very largely lost.

Two Units Giving Dissimilar Beams Are Not Recommended.—The Air Corps report perhaps did not give this feature the emphasis it deserves. The second landing-light is usually carried for two reasons; one, to have better illumination on the side of the airplane toward which the pilot is looking, or, by using both lights, to better illuminate obstacles; the other is for the sole purpose of increased reliability. Since incandescent lamps designed for 100-hr. filament life at 12 volts give a good color and contrast when operated at somewhat less than 12 volts and are not particularly unreliable for short periods of burning at slightly more than 12 volts, they have been accepted as the best all-round compromise for aircraft use. A more efficient lamp will burn out when the generator is charging the battery, and the less efficient lamp gives poorer color and, of course, decreased beam-candlepower. Under ordinary conditions, the experienced pilot makes a great many landings with only one landing-light.

Vertical Beam Spread.—The vertical spread desired is a function of the height of the landing-light mounting. Much greater vertical spread is needed for a high-wing cargo monoplane, such as the large three-engine commercial transports, than is required for the small low-wing monoplane or the lower wing of a conventional biplane. In my opinion, all the requirements can be most nearly met by a design incorporating a symmetrical, easily duplicated reflector, without spread lens, giving the same vertical and horizontal spread and a minimum of stray or spilled light.

Survey of Screw-Thread Practice

Sectional Committee and Bureau of Standards Checking Use of American Standard

UNDER the direction of the Sectional Committee on the Standardization and Unification of Screw-Threads, sponsored by the Society of Automotive Engineers and the American Society of Mechanical Engineers, with the Bureau of Standards cooperating, a comprehensive survey of screw-thread practice in the United States is now being made. More than 150 manufacturers and users of threaded products, so chosen that they constitute an average cross-section of industry, are being visited by the Committee's representative. Each firm is being requested to give five samples each of the following 12 sizes. Coarse-thread series 6-32, 10-24, ⅜-16, ½-13, ¾-10, 1-8 and 1¼-7; fine-thread series ⅜-24, 7/16-20, ½-20, ⅝-18 and 1-14.

Bolts, studs, nuts and tapped holes, in all about 3000 items, are being forwarded to the Gage Division of the Bureau of Standards, where arrangements have been made for accurate measurement of the various elements of the threads and comparison of these with the American National Standard.

The Committee's representative is also obtaining from each firm visited a complete report of its experience with American National Standard Threads and their gaging practice in the form of answers to a questionnaire.

Evolution of U. S. Standard

Many individuals, societies and organizations of various kinds have had a part in the development of the present American National Standard for Screw-Threads, which is now very generally recognized by both manufacturers and consumers in this Country. It was a long process, beginning with the gradual evolution of the so-called U. S. Standard. In 1907 the A.S.M.E. added the dimensions for machine screws and coarse and fine threads, and in 1911 the S.A.E. completed and published the fine-thread series, ¼ to 1½-in., inclusive.

The World War emphasized very forcibly the great need for uniformity in screw-thread practice in the United States, especially in regard to major diameter, pitch diameter and minor diameter, and the limits for these dimensions in several classes of fits. Accordingly, in July, 1918, Congress appointed the National Screw-Thread Commission. After three years of intensive work the first report of the Commission was issued in 1921. Industry, as represented by the Sectional Committee on Standardization and Unification of Screw-Threads, made a careful study of this report, and after joint conferences with the National Screw-Thread Commission, completed its first report, which became an American Standard and was published in May, 1924. This standard covers only screw-threads for bolts, machine screws, nuts and commercially tapped holes.

Commission's 1928 Report under Review

The second and third reports of the Commission were completed and published in 1924 and 1928, respectively. The 1928 report is the one now before the Sectional Committee for review. The present survey is intended to give authentic information upon which to base this review and the revision of the American Standard for screw-threads originally published in 1924.

After all samples have been collected and the measurements completed and tabulated at the Bureau of Standards, a report will be prepared by the Sectional Committee giving the findings in detail. This report will not identify the various cooperating firms with the particular samples which they will have supplied. This information, for obvious reasons, will be kept entirely within the files of the Bureau.

From the data obtained, the Sectional Committee will be able to judge the extent to which the American National Screw-Thread Standard has measured up to commercial requirements and in what respects revisions should now be made so that the standard can be made of greater service to American industry.

Division Reports to Standards Committee

ATTENTION of members of the Society, especially the members of the Standards Committee, is called to Section 2 of this issue of THE JOURNAL containing the reports of Divisions of the Standards Committee that are to be considered at the Summer Meeting at White Sulphur Springs. The reports will be considered at the meeting of the Standards Committee to be held Wednesday morning, June 17, following which those approved will be published in the Supplement to the 1931 S.A.E. HANDBOOK. The reports should be reviewed in advance of the meeting so that they can be considered and acted upon expeditiously by the Standards Committee.

Production Engineering

Fruits of Consideration

Mutual Regard Which Eliminates Fear and Promotes Loyalty Is Lauded by D. R. Grossman[1]

MATERIAL wealth has its good purposes and is very desirable; but, when the desire to acquire it supersedes consideration for the rights or welfare of others, then you see selfishness, dishonesty and greed in control. That kind of control will bring no end of trouble, such as some of the industrial difficulties that we are now experiencing. These motives are not confined to labor or to management or to ownership. Labor has its shortcomings. There are too many workers who, if they can avoid it, will not produce in proportion to their pay and too few who are really conscientious. On the other hand, few foremen and managers and owners are exactly eligible for prizes.

What is needed is more real, practical regard for our fellow man. That fact has been recognized by some industrial leaders who have had the courage to convert their convictions into action, with splendid results in many individual instances. That which has been done by some from the heart has been copied by others from the head. Any man or firm that is honest as a matter of policy is not really reliable. A really reliable man is honest because he loves honesty and loathes dishonesty. For some commodities there are no substitutes that are "just as good." Consideration for our fellow man, if it is to be effective, must be from the heart, not from the head.

This does not mean, however, that the head is not to be used. It is as necessary to see that you get what you pay for as it is to pay for what you get. Right results are not to be expected from condoning another's fault or from trying to correct it by a fault of your own. Suspicion is no virtue; it is better to be "hooked" now and then than to be always suspicious. Most men can be credited with good intentions.

Fear Begets the Thing Feared

Selfishness is really a manifestation of fear, and fear is often the factor that prevents the realization of good intentions. The workman fears the loss of his job and his ability to supply the needs of his family; he may try to make the work last longer by doing less of it each day, or he may resort to some other form of dishonesty. Management may fear a poor showing, a lack of profits. What is the result? Lack of proper consideration on both sides. The laborer loses his job, the manufacturer cannot sell his product, the fears of both are realized, and we have a depression which could have been avoided through the maintenance of confidence. Other factors may contribute to depressions, but lack of confidence is generally considered a major factor.

It has been stated that the present depression is due to overproduction. Can it be honestly stated that there is overproduction when we see on every hand actual need for every product? The Smith family needs bread, and the farmer wants to sell wheat. The farmer's children need shoes, and the head of the Smith family wants to produce them because he needs the work. The unbalanced factors are not due to material conditions, but to a lack of the proper exercise of mental functions.

Which side should be expected to take the initiative in giving the necessary assurances to establish confidence, to establish and maintain the proper balance and prevent the recurrence of depression? Should it be the side that is generally considered as having the less intelligence? Obviously, it is up to industrial management to adopt the correct attitude and do the necessary planning so that the average workman may be relieved, to some extent at least, from the worries to which he has been subjected in the past regarding his daily bread. The kind of regard for your fellow man that comes from the heart is conducive to the kind of confidence that wins over all obstacles. No man greatly fears evil or failure or feels the necessity of resorting to dishonesty when he is absolutely convinced that, as a result of constant, intelligent effort to accomplish a worthy purpose, he deserves to win.

Human Relations Begin at Home

We can well look within for a starting point in dealing with the human factor in industry. Having regard for others can easily be made a habit. Kindness and firmness can and should go hand in hand. The management of an industry might well look over its employes with a sympathetic eye for those who, together with the other necessary qualifications, have or can acquire the habit of consideration for others. Any who seem absolutely impervious to the habit should be eliminated or placed in obscure positions until they have acquired a taste for it.

Foremen should be particularly adaptable. Strict honesty and a capacity for intelligent sympathy should be an absolute requirement. They are the key men in dealing with the human factor in industry. I am afraid that too many of the foremen employed today are of the old school. Education or elimination must inevitably come about.

This idea alone will not bring the desired results. What we have learned from the efficiency experts, the research laboratories and specialists regarding all the details included in correct procedure must not be disregarded; in fact, all of these activities must be continued with even greater zeal. But you might as well try to succeed by throwing away your "slip-sticks" or ignoring the multiplication table as to disregard the human factor in industry.

Understanding Essential to Cooperation

The time is here when it is essential for each department of an organization to have a general and sympathetic understanding of other departments. This applies particularly to engineering, research, production, sales, service and accounting; mutual understanding is necessary as a foundation for the best cooperation.

The membership of this Society consists largely of engineers, research workers and specialists who are accustomed to searching for new ideas and creating new plans. You recognize the value of a good idea as compared to a poor one; you know the importance of ideas and the necessary thinking and experimenting usually involved in their discovery. What part of the industry is better equipped to grapple with the problem and produce constructive ideas that are fair to all, including the merchandisers and the users of our product?

You know that your own work is no better than your thinking. By thinking, you arrive at an idea which you outline on paper in the form of a blueprint—of a crankshaft, let us say. The necessary dies and tools must be made. Your idea must become the idea of everyone who has anything to do with the making of the shaft.

[1] A.S.A.E. — Vice-president and general manager, Studebaker Corp. of Canada, Ltd., Walkerville, Ont. From an address given before the Canadian Section.

If the crankshaft is to correspond exactly with your idea, there must be some exact thinking going on all down the line. Can a mind that is filled with fear, hate, revenge, sorrow or suffering do a good job of thinking? If the idea is good and the thinking that produces the shaft is correct, it goes into a car and gives good service. But even the inspector may have his own private worries; and, when a shaft gets by that causes trouble, we say that it is a defective part. Then there is a disappointed car owner and loss and dissatisfaction all around. If enough of that kind of thing goes on, there is a bankrupt dealer and another factory gone out of existence, all because there was defective thinking. So you can readily see the importance, from what is generally termed the practical viewpoint, of encouraging the correct mental attitude on the part of everyone connected with our industry.

Growth Exceeds Own Merits

Our industry has experienced a phenomenal growth, but it is possible that that growth has been due more to the natural desire for ownership of the product than to methods used by the industry. While the cost of owning a car has been greatly reduced, and ownership in a great majority of instances increases the usefulness and consequent earning power of the individual, still the total cost of individual transportation is too high. That the public is not standing, and much less is aware of, the full cost is evidenced in the used-car situation. The lack of profits and the losses of dealers must, if the industry is to survive, either be added to the cost to be borne by the public or be absorbed through greater efficiency in the manufacturing or merchandising and servicing divisions of the industry.

How Growth Can Be Continued

The solution is not cheaper cars but better cars, cars in which the assured mileage without excessive repair cost is more of a known quantity, cars that are more impervious to the lack of proper treatment at the hands of average owners, cars that cost less to repair when repairs are necessary, cars that are not depreciated so much through mere changes which are not improvements.

Our material advancement has been rapid, but it can be still further enhanced by consciously attributing to mental attitude and thinking the importance which they deserve. Instead of listing the factors with which we deal as money, material and labor, we should rank them as ideas, labor, money and material. It has always been assumed that ideas and thinking were essential, but I claim that they have not generally been given a place in accordance with their importance.

There is not one of us, no matter how efficient, who cannot increase his efficiency through proper care of his thinking. The mind consists of the thoughts which compose it, yet most of us are more careful of what we eat than of what we think. Food for thought should be selected with at least as much care as food for the body. Correct thought includes nothing that is unkind or selfish, and this fact should be kept strongly in view in dealing with the human element in industry.

Grinding Tungsten-Carbide Tools

THE MOST RECENT experience of the General Motors Corp. in regard to grinding tungsten-carbide tools was given by William H. McCoy at a recent meeting of the Dayton Section. Much of the information on general experiences and results with these tools which Mr. McCoy gave at the Production Meeting in Detroit last October, as reported in the S.A.E. JOURNAL for November, 1930, p. 557, was repeated at this meeting. Following is what Mr. McCoy had to say about grinding:

Cemented tungsten-carbide, a mixture produced by pressing and sintering finely divided tungsten-carbide in a matrix of cobalt, has a metallic luster, but it is not steel and should not be treated as steel. The problem in grinding is to produce economically a clean, sharp edge, with correct rake and other angles, without undercutting the cutting edge and without checking or cracking the tip of the tool.

However, tungsten carbide differs so much from high-speed steel in its nature that it requires different methods and technique in handling to grind it successfully. Its hardness is so great, as compared with other materials, that the cutting edge tends to chip easily during the grinding operation, and the sharpness of the cutting edge is so important in relation to the efficiency and productivity of the tool that grinding wheels which are quite different from those in common use in tool-rooms are required, as well as special devices and methods of feeding and more care throughout the grinding operation.

We have found the Green Grit wheel to be the best, made in different sizes of grit or grain for various purposes, Mr. McCoy continued. The grits and bonds we have found most suitable are as follows: for roughing, 60R mesh with soft bond; for semi-finish grinding, 80R mesh with medium bond; and for finishing, 100T to 120T mesh with hard bond. The most important points in grinding are to have the cutting surface remain sharp, the bond giving way, and to grind against rather than away from the cutting edge of the tool.

At different times we have been asked whether wet or dry grinding is the better method. Both methods are used successfully in commercial practice. Dry grinding is satisfactory, especially where a small amount of stock is to be removed, when the pressure of the tool against the wheel is kept low and care is taken to prevent overheating. Wet grinding is to be preferred generally, provided that the supply of water is ample. A little water is worse than none. Because the wheel is less likely to load when used wet, and because of the absorption of heat by the water, the cutting edge is kept much cooler and the harder grades of bond can be used with better results. About one grade harder can be used in wet grinding than in dry grinding. A tool that has become heated in dry grinding can be cooled by dipping the shank in water, but not the tip itself.

Results obtained in the various divisions of the General Motors Corp. indicate that tungsten carbide as a cutting material is here to stay, and we expect to find more uses for it from day to day. It is replacing not only cutting and turning tools but also reamers, spotfacers, milling-cutters, sizing rings and drawing dies of other materials. It is being used on measuring instruments such as plug and ring gages and indicator points.

We have had very little success with tungsten-carbide tips on twist drills or with tungsten-carbide turning-tools on soft steels. The failure with this material is due to the high heat conductivity of the tool tip. A great amount of heat is generated and the conductivity of the tip is greater than that of the material of the tool shank or of the material that is being cut. Two things are liable to happen because of this: first, the shank may heat and expand away from the tip, breaking the bond; second, there is a tendency to alloy between the chip and the excessively hot cemented tungsten carbide. The latter effect, which causes most of the failures, is not so noticeable when cutting steel in the Brinell-hardness range of 220 to 260. When cutting soft steel, a small fin appears on the cutting edge, then the fin breaks off and takes with it a small portion of the tungsten-carbide tip. We believe that these failures can be overcome by increasing the size of the tip enough to cause the heat to be conducted away rapidly, so that the temperature of alloying is never attained under ordinary working conditions.

Transportation Engineering

Ice-Company Driver-Practice

R. H. Van Ness[1] Outlines How Drivers Can Operate Heavy Ice-Delivery Motor-Trucks Safely

A MOTOR-TRUCK driver is known by motor-transport executives as a "key" man. He can minimize the cost of the transportation produced by the vehicle, or he can do exactly the opposite. Whichever he does depends largely on his mental attitude toward his job. Each driver is guardian of a company vehicle which represents a large investment, and the company desires that he take as keen an interest in protecting and maintaining the vehicle he operates as though it were his own. The company has done everything within its power and means to provide each driver with a vehicle that is easy and safe to operate. With the aid and cooperation of each driver, the company can afford to keep to this standard, which is a credit to the organization and a benefit to all its drivers.

The company has spent and is spending large sums to purchase equipment that is not only safe and easy to operate but affords considerable comfort to the driver. If he becomes a cooperator and desires to follow the rules and regulations as outlined, he will help to lighten the burden that the ice industry has been shouldering which is a high delivery operating cost for a low-priced merchandise. With a little forethought and consideration, the drivers can help master this situation. A few rules and instructions are outlined herewith as a helpful guide for them.

Helpful Hints to Drivers

In making a complete success of his day's work it is very essential that each driver report for duty in a good frame of mind, and that he know the condition of the vehicle assigned to him before he leaves the garage. His further duties are to

(1) See that the gasoline tank contains sufficient gasoline to complete the day's run without exhausting the fuel supply. The safe way to prevent running out of gasoline is to fill the tank daily.

(2) Make sure that the engine has sufficient oil. This can be determined by an oil-level gage or by a pet cock, which generally is on the same side of the engine as is the filler standpipe. To find the actual oil-level press down on the gage pin, if of the float type, and note whether the pin rebounds to a position opposite the line marked "full." If of the pet-cock type, the upper pet-cock which is at the engine level must be opened and a wire, if necessary, be inserted to remove obstructions so that the oil can flow freely.

(3) Remove the radiator cap and examine the inside of the filler pipe to determine the water level. If water is up to the overflow pipe—located within the filler pipe a few inches below the neck—this indicates that there is sufficient water. If it becomes necessary to replenish the water supply, make sure after filling the radiator with water that there are no leaks. In most cases a leak is indicated if the water level falls rapidly below the overflow pipe.

Specific Safety Rules

After taking the foregoing precautions, the driver is then ready to start the engine. In doing this, observe the following safety rules:

(1) See that the spark-control lever is retarded to a proper position for starting and will not cause a kick-back; otherwise, if of the starter type, you are very apt to break the starter. If of the type that obliges you to crank the engine by hand, use greater caution so that you will not run the risk of breaking your arm or wrist.

(2) For the selective type of transmission, see that the gearshifting lever is in a neutral position. For the planetary type, be sure that the low-speed pedal is half-way depressed and that the hand-brake lever is pulled back as far as possible.

(3) Note whether the hand brakes are applied so that the vehicle, if the brakes are in good condition, has no chance to creep forward and cause personal injury or property damage if you are obliged to start the engine with a crank.

(4) After all these precautions have been taken, place the ignition switch in the operating position. Then pull out the carbureter-choke rod—if the weather is cold—and turn the engine over either with the hand crank or by pressing the starting-motor pedal. Never hold the carbureter-choke rod out, because this might flood the engine with gasoline.

(5) After the engine starts, do not race it to a high speed before it has had time to warm up and thin the oil sufficiently to cause a film of oil to cover the moving parts.

(6) When taking the vehicle from the garage, make sure that you do not strike or disturb any other object. At no time proceed at a high rate of speed. Always *stop* when you reach an exit and look for dangerous conditions before driving out on the highway.

(7) Immediately after leaving the garage, test the brakes. If not in a safe operating condition, return the vehicle to the garage at once and get one that is in good operating condition. If no spare truck is available, wait until the brakes are properly adjusted before operating the vehicle on the highway.

(8) After assuring yourself that the vehicle is safe to operate, continue to the point where you are to receive your truck load. Make sure that your way is clear before backing up to the dock or platform. Do not back the vehicle so fast that it will strike with terrific force, distort the truck and damage the dock; be careful.

(9) When receiving your load do not allow the ice to be dropped onto the bed of the truck; lower it easily and slide the ice into position carefully to prevent cracking the ice and damaging the sides of the truck. After loading, cover the ice with tarpaulin so that it will preserve the ice, but do not use tongs to pull the tarpaulin because a small tear in the fabric will cause fast deterioration of the canvas.

(10) After you have received your truck load and made all necessary arrengements at the scale office or dock, proceed to the first point of distribution, remembering your position as a public servant.

Rules of the Road

(1) Drivers of company-owned vehicles must practice the courtesy of the road toward drivers of other vehicles and to pedestrians.

(2) The driver of a motor-vehicle must clearly signal his intention of turning or stopping.

(3) Upon a signal from a vehicle approaching from the rear, the driver of the motor-vehicle shall concede the right of way.

Safe Operation of a Motor-Vehicle

During the day's work, each driver should follow the operating rules so as to maintain a factor of safety and preserve the rights of others.

(1) The engine must not be left running unnecessarily when the vehicle is standing on the public highway unattended.

(2) A driver shall not permit unauthorized persons to drive or operate the vehicle which has been assigned to him. Neither the public nor employes not in their regular line of duty shall be permitted to ride on company vehicles.

(3) All traffic and automobile laws in the respective localities shall be observed strictly. Drivers shall have their vehicles under full control at all times. Reckless driving will not be tolerated. Existing conditions determine "speeding" and "reckless driving."

(4) The indiscriminate use of horns or other signaling devices will not be permitted. They shall be used as a warning only.

(5) When stopped on a grade, drivers must be sure that the brakes are properly applied and that they have set the wheels at an angle against the curb where this is possible. This must be done at all times, whether the truck is facing up or down grade.

(6) Trucks must never be parked on bridges or curves.

(7) Attempt must not be made to pass

[1] M.S.A.E.—Superintendent of transportation, City Ice Co. of Kansas City, Kansas City, Mo.

other vehicles on curves, grades or street intersections where the view is obstructed.

(8) Trucks or cars operating in the same direction as other vehicles must stay a safe distance behind such other vehicles. On slippery streets drivers must always allow a safe distance within which to make a stop, leaving the truck in gear and applying the brakes until the speed of the truck has been retarded sufficiently to disengage the clutch without danger of skidding.

(9) When fire-department vehicles, ambulances or police patrols are heard or observed approaching from any direction, trucks must be stopped as close to the curb as possible and held there until the special vehicles have passed.

(10) A positive stop must be made at the door of any building or enclosures, and the horn sounded when entering or leaving.

(11) When blinded by glaring headlights drivers must slow down and, when necessary, stop. In fog, the driver shall keep the truck under control so that he may be able to stop within his range of vision.

(12) When proceeding down grade, the clutch must not be disengaged. The engine should be throttled.

(13) Trucks shall not be operated with tail gates hanging or dangling. When possible, tail gates must be fastened up securely.

(14) Slow-moving vehicles should keep to the right of the highway to allow faster-moving vehicles to pass.

(15) Drivers of all passenger-carrying types of company vehicles, or privately owned vehicles when on company business, must assure themselves that no trains are approaching before crossing any railroad. The drivers of all company-owned trucks or commercial automobiles must bring their cars to a full stop at all railroad crossings and assure themselves that no trains are approaching before proceeding. This does not necessarily apply to crossings that are protected by gates or watchmen.

(16) When approaching road intersections, drivers shall reduce speed and be prepared to stop. Traffic approaching from the right shall be given the right of way.

(17) Employes shall not be permitted to ride on trailers that are being drawn by trucks.

(18) Trucks or trailers stopped on highways shall be properly protected by red flags by day and red lanterns by night.

Closing the Day's Work

After a driver has completed his day's work and returned his truck to the garage, he is requested to comply with the following program:

(1) Make sure you fill the gasoline tank to within 1 in. of the top of the tank.

(2) Examine the oil gage and replenish the oil supply.

(3) Place the truck in its allotted stall; do not back it against the wall at any time. Always make sure that the tail gate is up and in a closed position.

(4) A driver must report his truck upon returning to the garage. If any repairs are necessary it is his duty to report them on the sheet used for that purpose at all company garages. If the repairs needed are serious, the driver should make it his business to notify the foreman of the general shop or the man in charge of that sort of repair and request that it receive immediate attention.

(5) The driver should then fill out the daily truck report. This is used to determine the amount and the cost of the work accomplished. It guides and economically controls the operations. It must be made out correctly.

In conclusion, success is dependent upon the aid of the men who work with our company *conscientiously*, and not by men who merely work for it.

Traffic-Congestion-Relief Problems

TYPICAL problems which bear upon the relief of traffic congestion and that require thorough research and experimentation, are presented herewith. The problems were stated by the Third National Conference on Street and Highway Safety, which recommended that comprehensive studies of such problems of congestion as affect public safety, the stability of property values and the orderly development of urban communities be conducted.

(1) The relation between traffic and transit conditions and facilities and the trends in centralization or decentralization of cities with particular attention to the effects of these trends upon the stability of property values and upon the efficient conduct of business, upon living conditions and upon the public welfare generally.

(2) Factors to be considered in determining the relative advantages and cost of several possible programs of increasing street capacity; that is, widening of existing main-traffic streets, development of new thoroughfares, double-deck highways, arcaded or elevated sidewalks and the construction of off-street transit facilities.

(3) Comparative advantages and cost of the widening of radial traffic arteries from a central business area, and the construction of bypass routes to relieve that area of traffic not destined thereto.

(4) The relationship of building bulks and intensity and character of lot occupancy to traffic density and transportation requirements.

(5) Comparison of various street-intersection designs existing or proposed, with respect to traffic facilitation, safety and cost.

(6) The relation between automobile speeds, street capacity and accidents.

(7) Effective traffic capacity per lane of highways of various widths and characteristics.

(8) The effect of standardization of traffic regulations upon accidents, speed and street capacity.

(9) Factors which should determine public policy with respect to railroad or highway grade-separation.

(10) Principles which should guide in planning public transportation facilities as part of a city plan.

(11) Effect of various types of traffic control and particularly signals upon the capacity of streets, the movement of traffic and public safety.

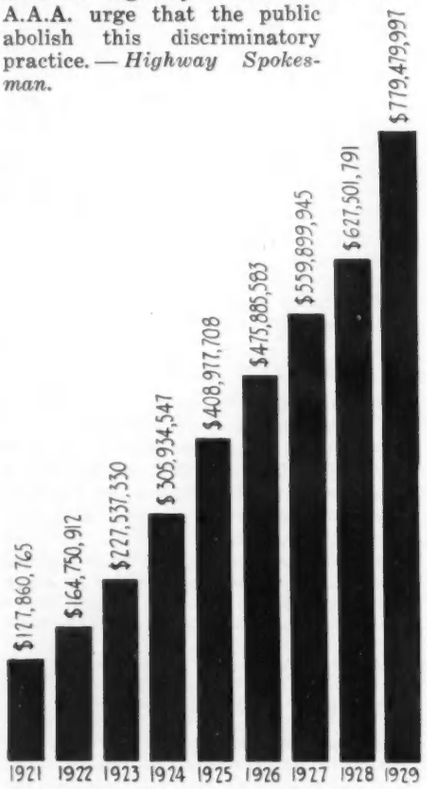
(12) Factors to be considered in the planning of express parkways, main-traffic highways or super-highways in the residential environs of metropolitan areas.

(13) The economic relationship of street and highway lighting to traffic facilitation and safety.

(14) Characteristics of various types of pavements, and effects of defective pavements, in relation to traffic capacity, speed and accidents.

Auto-Tax Diversions Harmful

A FOUR-LANE super-highway long enough to connect Washington, D. C., and Denver, Colo., could have been constructed with the money which has been diverted from special motor-vehicle taxes during the last five years, according to statisticians of the American Automobile Association who estimated recently that diversion of motor-vehicle taxes from highway construction and maintenance had exceeded $90,000,000 since 1925. This sum would have more than paid the cost of right-of-way, grading, drainage, engineering and administration in the construction of a modern concrete road 1800 miles in length. Instead, the money was used for financing State governments, school systems, flood relief and other projects entirely unrelated to highways. Officials of the A.A.A. urge that the public abolish this discriminatory practice. — *Highway Spokesman.*



AMERICAN AUTOMOBILE ASSOCIATION CHART SHOWING THAT MOTOR-VEHICLE TAXES HAVE MOUNTED ELEVEN TIMES AS RAPIDLY AS HIGHWAY EXPENDITURES DURING THE LAST TEN YEARS

	1921	1929	Increase, Per Cent
Special Motor-Vehicle Taxes, Not Including Personal-Property Tax	$127,860,765	$779,479,997	509.7
Motor-Vehicle Registration	10,463,295	26,501,443	153.3
State-Highway and Local-Road Expenditures	994,103,567	1,444,668,985	45.3

News of Section Meetings

(*Continued from page* 619)

apolis race or other races governed by the same type of rules, five entries have 16-cylinder, six have 8-cylinder, one has 6-cylinder and two have 4-cylinder engines. The average displacement of the 14 engines is 242½ cu. in.

Rules for the 1930 Indianapolis race virtually obsoleted the midget class of cars that had borne the greatest burden of recent racing and about 40 of which cars were in the hands of owners and drivers. Much thought and work have been put into revamping these, said Mr. Duesenberg, to bring them up to the necessary efficiency without superchargers, and engineers will do well to follow up those that make a good showing in this year's race.

The revamped stock-car class had 28 entries, all but three of which have eight-cylinder engines, the three exceptions having four-cylinder engines.

Tables accompanying the paper gave the names of the cars and their drivers, number of cylinders and the bore, stroke and piston displacement.

A Combustion Efficiency Indicator

Great interest was taken in a paper presented by Dr. Miller Reese Hutchison describing the Moto Vita, illustrated with lantern slides shown and discussed by M. E. Cheney, chief engineer of the Moto-Meter Gauge & Equipment Corp. This new device, the patent rights to which have been acquired by the Moto-Meter corporation, was described as an extremely delicate qualitative instrument that will show quantitatively the relation existing between different exhaust gases when the engine conditions are altered, as by variations in the combustible content in different cylinders of an engine under uniform and constant operating conditions. It is actuated by the calorific value of the unburned gases emitted in the exhaust and can be used for analyzing the exhaust from all cylinders collectively or the dynamometer test-set that has been developed can be used for investigating the manifolding, distribution, or the action of single cylinders. It can be used in the check-up and adjustment of carbureters and to obtain an accurate check on production engines as well as in determining the uniformity of distribution of the fuel to the various cylinders.

Factors Affecting Combustion

D. M. Pierson, assistant chief engineer of the Chrysler Corp., presented a paper on Some Factors Affecting Combustion. This was a comprehensive technical paper in which the author started with the carbureter as a metering device for supplying the correct air-fuel ratio for all engine operating conditions and discussed the fuel-distribution and combustion system progressively, ending with the spark-plugs. He pointed out the importance of atomization of the fuel at low engine-speeds and the application of heat to effect such evaporation.

Investigations have proved, said Mr. Pierson, that the maximum advantage in combustion is obtained if a predetermined air-fuel ratio is maintained at low temperatures. Under cold-starting conditions, a correctly proportioned mixture under full-choke operation has resulted in consistent and satisfactory starting of a number of different types of engine. With such a ratio and increased atomization by the carbureter, economies of 76 per cent in storage-battery discharge current per engine start and equal reduction in volume of fuel per start have been realized in experimental studies at zero deg. fahr. and with standard winter gasoline.

Intensive study of fuel-air movement in the manifold is made more necessary than heretofore because of the more general use of air-cleaners or the combined air-cleaner and silencer, said Mr. Pierson, in discussing the effect of manifolds.

With regard to compression, the speaker stated that in an effort to gather more data, 60 cars of six and eight-cylinder models are being operated in territories from coast to coast and from Toronto, Canada, to Oklahoma with the compression ratio increased 30 per cent. So far the indications are that, even with this increased compression, the inertia loads of the reciprocating parts predominate mechanically and that more accurate spark-timing synchronism is definitely needed.

Ignition was also dealt with at some length. Fouling of the spark-plug insulator and preignition from overheating may perhaps be due to oxidation of finely divided metallic iron in the lubricant at the higher engine temperatures and its deposition on the hottest parts of the combustion-chamber. Carbon collection on the spark-plug core is mainly due to delayed temperature rise of the plug during accelerating periods, owing to design of the plug. To avoid this, some car manufacturers, concluded the speaker, are now using plugs of 14-mm. thread pitch rather than the present standard 18-mm. plug.

Five-Hour Session on Brakes

Subject Fails To Stop Baltimore Meeting Until 2½ Hours Beyond Usual Limit

LONG after his discourse had been concluded and the meeting officially adjourned by Chairman Pooley, Alvin M. Yocom, chief engineer of the Multibestos Co., was being plied with questions and drawn into conversation by first one member and another, until at 1 a. m., 5 hr. after he was introduced to the Baltimore Section at its meeting on April 16, he was borne to his train directed toward Boston. The spirit of the man and the willingness of the flesh to continue discussion were admirable. The broad and practical knowledge of his subject was evident and impressive to all of the 115 members and guests in attendance, and the meeting was another in the chain of successes, as all agreed that automobile braking systems are due for further engineering development.

Mr. Yocom's address, entitled Reasons and Remedies for Variations in Brake Operation, covered every known problem confronting engineers and service men in regard to brake maintenance and performance, including friction and its characteristics, factors in friction contact, shoe and band contacts, linkage, noises, scoring, equalization, grabbing, slipping, variations in temperature of drum, of lining, of friction, and lubrication.

The speaker's first illustration was of the arc of contact, showing that when the arc exceeds the angle whose tangent is equal to the coefficient of friction between drum and lining, specific normal pressure becomes infinite, the brake-drum becoming distorted and grabbing action taking place.

Drum-Elasticity and Contact-Arc Effects

"Due to drum bulge," stated Mr. Yocom, "or perhaps shoe deflection, considerable vibration can be set up and, if the frequency of these elastic vibrations is very high, a shrieking brake will be the result. If the parts are less rigid, the frequency of vibration will be less; if the parts are still less rigid, brake chatter is experienced and finally the grabbing begins. In-

creased rigidity, however, is not a cure for all brake evils, because it is impossible to make parts so rigid that they will withstand infinite forces.

"If the arc of contact in internal brakes is made too great, there is a tendency for the brake to grab, squeal or chatter; on the other hand, if the arc is made too small, the specific pressure becomes too high, with the result that the heat cannot escape rapidly enough and the lining will reach a high temperature."

Of particular note during the course of the talk was the ability to supply remedies for correcting faulty brake operation of any character. In speaking of linings, Mr. Yocom said, "Some engineers are of the opinion that the longer the lining of a shoe is, the longer the life will be. This would perhaps be true if the normal pressure against the lining were equal at all times but would not be effective where the initial pressure is applied at the free end of the shoe. When pressure is applied to the free ends, the forward-acting shoe, having positive actuation, will exert a greater normal pressure on its side of the drum and cause distortion."

"I really believe," continued Mr. Yocom, "that brake-lining manufacturers have made considerable progress in the last few years on linings that are beginning to show a uniformity of coefficient of friction, but no matter how finely engineered or designed a brake may be, it will be a failure if used with poor lining. The characteristics of the lining control the characteristics of brake performance.

"In our method of bonding asbestos with latex we find the improvements as follows:

(1) Decrease in wear factor that reduces the number of adjustments of brakes

(2) Friction increases with temperature increase—a factor that improves brake performance when making stops from high speed or in checking car speed on long steep grades

(3) Reduction in drum-scoring tendency that reduces service charges

(4) Prevention of what is known as damp-weather brake sensitiveness—a factor that causes many dealer-to-factory complaints

(5) Damping of vibrations which cause noise.

"While there are variations in brake performance, it is believed that most of these are due to faulty servicing or lack of brake servicing. To improve designs so as to prevent this faulty brake servicing by making adjustment easy, it is safe to say that the brake and lining divisions of the automotive industry are spending $500,000 each year on research work. Considering weight, cost and performance of the modern brake, it must be agreed that the brake engineer has done his work well and has designed a safe smooth-performing brake."

Scientific Carbureter Adjustment

Professsor Baender Explains Gas-Analysis Method at Northwest Section's Closing Meeting

THE FINAL meeting of the season of the Northwest Section was held in Seattle, at the New Washington Hotel, Friday evening, May 8, with well over 100 present. Don F. Gilmore, who served very capably during the last year, turned the gavel over to C. H. Bolin, newly elected Section Chairman.

The address of the evening was by Prof. A. G. Baender, head of the engineering department of Oregon State College, his subject being Scientific Adjustment of Automotive Carbureters. He treated the subject purely from a technical standpoint, going into detail as to the chemistry of reactions involved and analysis of exhaust gases in order to arrive as nearly as possible at a perfect air-fuel mixture in the carbureter.

Chairman Gilmore announced plans for a visit by members of the Section to the Skagit hydroelectric project of the City of Seattle on June 27 and 28. Reviewing the year's work, Mr. Gilmore stated that 12 meetings had been held, including one at Vancouver, B. C., where plans are under way for a new Section, and that 20 new members were added to the Section.

Roy Howard, of Vancouver, who was present, invited the engineers to hold a midsummer meeting for two or three days in the Canadian city, when the proposed sub-Section group may be launched on its career. This session probably will be in August.

The tellers of election reported the election of the following officers to serve for the coming year: Chairman, C. H. Bolin; Vice-Chairman, James H. Frinck; Treasurer, Charles C. Finn, and Secretary, John G. Holmstrom.

Professor Baender, with a piece of chalk and a blackboard as his main tools, went fully into the fundamentals of carburetion and combustion in an engine. "It is folly to throw away heat in carbon monoxide," he declared, "and when the analysis of exhaust gases shows that this is being done, the fault lies in improper adjustment of the carbureter."

Significance of Gases in Exhaust

The establishment of a fuel-air ratio that is correct for the engine's use depends on four gases, he stated; namely, carbon, hydrogen, nitrogen and oxygen. The emission of carbon monoxide and oxygen should be as nearly eliminated as possible, as in theory they are entirely absent if combustion is perfect. When carbon and oxygen unite to form carbon monoxide, only 4500 heat units, for an equal volume, are formed compared with 14,500 heat units when sufficient oxygen is present to form carbon dioxide.

"The only infallible method of determining whether the gasoline and air burn in proper mixture," said Professor Baender, "is by testing the exhaust gases. If the ideal mixture were attained, which it never is, only three gases would be found at the exhaust—CO_2, H_2O and N_2. If we find CO, the mixture is too rich, so the need is for more air in the carbureter."

Theoretically, the percentage of CO_2 that an analysis of the exhaust gases will show when the mixture is correct is 13.8 per cent. But in practice, if the percentage is 11.5 or not more than 12.5, the mixture is regarded as the best attainable for efficient operation. An excess of air, containing too much free oxygen, is indicated when the analysis shows a low percentage of CO_2. When the percentage is 12, it means that the air has been cut as low as is safe, while going beyond that would make the "balance" too nearly perfect, so that some gasoline will never find oxygen and would go to waste, unburned. When the mixture is too rich, the CO gas is formed to excess, there being a shortage of O molecules, and there is not only danger to health, but also a loss of two-thirds of the heat units.

The method of carbureter adjustment, as explained by Professor Baender, is to idle the engine and apply the machine made for testing the exhaust gases, analyzing samples at frequent periods and adjusting slowly until the desired percentage of CO_2 is given. The analysis depends on absorption of the gas in a solution of caustic soda, where the reduction in volume of the original sample gives the volume of carbon dioxide. The adjustments are suitable for any of the common gasolines and, when once adjusted, no change is required when a different standard brand of gasoline is used.

Aviation Meeting Closes New England Section Season

AVIATION will progress in the next few years so that there will be small airports within 10 miles of big cities to which small planes will taxi passengers from the transport terminals to the homes of suburbanites, said Major Gill K. Ervin, of the aeronautic department of the Shell Eastern Petroleum Products Co., at the final meeting of the season of the New England Section at the Hotel Kenmore, Boston, the night of May 19. He stated that it was difficult to predict what 10 years will bring in the type of aircraft, now that

it is possible to make nearly vertical take-offs and landings. His talk was about the development of airports in this Country.

How Aviation Developed

Beginning with the time when Army pilots picked out landing-fields because of being forced down, Major Ervin explained how two routes were charted across the Country in the early days and a volume of data gathered that was afterward very valuable when a definite aviation section was created by the Federal Government. He traced the successive steps by which interest was created in aviation from 1919 on, and the great forward step it took after Colonel Lindbergh's flight. He contended that there are similar problems for aviation to solve as have been worked out by railroads, steamship lines and other transportation agencies.

The speaker explained the different types of airports, as the municipal, the corporation owned, and those owned by individuals. The corporation fields are handicapped by heavy overhead because they were bought when prices were at the peak, he said, and suggested that to meet overhead they follow the plans of municipal fields to attract people by having swimming pools and playgrounds and making a reasonable charge for getting to and from them. He detailed what constitutes a Class A airport.

Asked about the landing places in the ocean, Major Ervin stated that experience only can determine their usefulness.

Getting Pictures of Bremen Fliers

Lieut. Robert S. Fogg, of Concord, N. H., who made the flight to secure the first pictures for a news reel company when the Bremen transatlantic fliers landed at Greenly Island, gave an address on that trip. It was a very interesting story about the difficulties that had to be overcome in getting the pictures, which were taken by Tommy Hogen, the camera man. Many amusing experiences on the trip were narrated. His meeting with Major Fitzmaurice, when the Irish aviator landed at a little place in Quebec after being rescued from the island, was also interesting.

Asked what he thought of the northern route to Europe, Lieutenant Fogg said that it is very feasible and stated that 18 large cities in this Country are nearer to 18 large ones in Europe by the northern route, as the longest water jump is only 650 miles and there are plenty of landing places in emergencies. On the other hand, the water route by way of Bermuda has a 2000-mile jump.

Chairman Albert Lodge announced that the new officers elected were Robert F. Lybeck, Chairman; Dean Fales, Vice-Chairman; Fred Herlihy, Secretary; and A. F. Postal, Treasurer.

Oregonians Hear about New Traffic Code and Diesels

THIRTY-NINE members and guests turned out to the Oregon Section meeting in Portland on May 8. Although one of the smallest meetings of the year, it was not lacking in enthusiasm. Mr. Clark had arranged a snappy program of piano solos, singing and dancing numbers that enlivened the dinner.

Capt. J. J. McMahan, in charge of the Portland office of the State Traffic Department, gave a digest of the new Oregon Traffic Code to go into effect July 1, particularly that part pertaining to the operation of trucks and motorcoaches. New features of the code are the substitution of a safe-driving clause for the speed limit of the past, placing responsibility on garages and service stations to report cars coming to their attention which show indications of having been in a wreck or hit by a bullet, and the provision for examining new applicants for drivers' licenses.

Following the definition of a Diesel engine, as accepted by the Diesel Engine Manufacturers Association, and a brief outline of the fundamental cycle, Ben D. Asher, Oregon representative of the Worthington Pump & Machinery Corp., gave a complete description of the Worthington Type B four-cylinder four-cycle 300-hp. engine. Lantern slides were shown to illustrate many of the details of construction and parts of the engine.

S. B. Gorbutt, chief engineer of the Willamette Iron & Steel Works, of Portland, gave a detailed description of the construction and operation of the Bosch fuel-injection pump and the Bosch fuel-injector, also illustrated with lantern slides.

Chairman Drake appointed a tally committee to open and count the votes for officers for the coming Section year, and the result of the election was announced as follows: H. W. Drake, Chairman; H. W. Roberts, Vice-Chairman; J. Verne Savage, Treasurer; and M. T. Clark, Secretary. Some plans for next year's activities were discussed and further details of the Section summer meeting to be held the first part of June were planned.

St. Louis Section Considers Aviation Fuels

MAJOR J. H. DOOLITTLE was the speaker at the April 28 meeting of the St. Louis Section, and his topic was Aviation Fuels. The obvious answer to the aircraft engine manufacturers' dream of increased speed and payload is not to come in the form of a straight-run gasoline, he said, but lies in the utilization of the ordinary crudes available and, through a new method of manufacture, incorporating the several desirable qualities in the finished product. He predicted that, as a result of an extensive research that has been conducted for some time by the Shell Petroleum Corp. with which he is connected, a super-fuel for aviation will be available in the near future that embodies the following characteristics:

High Knock Rating

Good distribution, giving rapid acceleration and enabling the engine to operate economically without overheating
Good starting, especially in cold weather
Low vapor pressure, giving avoidance of gas lock
Stability, so that it will retain its characteristics during prolonged storage
Freedom from sulphur
Freedom from gum
Low weight per British thermal unit, minimizing the weight of fuel carried and increasing the payload
Low cost

The fuel of the future, said Major Doolittle, must permit advantage to be taken of increased engine-speed, compression ratios and brake mean effective pressure without reduction in reliability. Lack of a universally available aviation fuel of the high standard required has prevented transport airlines from using the most efficient engines available. Responsibility for enabling airline operators to adopt these excellent engines lies with the fuel refiners, asserted the speaker. When they have made the desired fuel generally available, aviation will have overcome one of its serious handicaps and the efficient operation of air transport will be assured.

Fleet Maintenance Discussed at Los Angeles

FRIDAY evening, May 8, at the Alexandria Hotel in Los Angeles, the Southern California Section devoted its monthly meeting to the subject of Maintenance. Chairman F. C. Patton introduced as the first speaker Thomas H. Mackechnie, of the Southern California Telephone Co., who described the maintenance operations of the company, which follows the rules laid down by the Bell System.

Mr. Mackechnie declared that the 900 units operated in the Southern Area by the telephone company are divided among 17 housing headquarters, each of which is in charge of an inspector. The company maintains no overhaul facilities. Minor repairs are made by the inspector and his assistant, while major repairs that cannot be taken care of by the inspector are made by the nearest agency for the vehicle, or by the nearest reputable garage. No tow car is maintained, a unit that breaks down on the road being repaired by the nearest capable garage.

The speaker declared that his company has found this system of maintenance to be more economical than any which calls for a complete main-

tenance headquarters operated by the company.

James C. Bennett, of the Associated Oil Co.'s San Francisco headquarters, was the next speaker. He declared that the transportation department of the company is an entirely separate department. Other departments rent their transportation from his department at so much per mile.

The company has 900 pieces of transport equipment spread over five States. The maintenance and storage of the units are taken care of by public garages at the central point in each district. Master mechanics, traveling in each territory, supervise the general maintenance, check repair bills and confer with the drivers.

Mr. Bennett produced figures showing that an economy has been effected by this public-garage maintenance system as against operating its own maintenance system over such a far-flung territory.

Railway Company Bus System

Doyle Rishel, of the Los Angeles Railway, concluded the maintenance program with a graphic description of the repair shops maintained for his company's bus system. Particularly interesting was his portrayal of the repair pits, of which there are 15, each accommodating two of the largest transport units operated by the railway. These pits have every modern convenience for the inspection and overhauling of the buses. The pits are intercommunicating and have recesses for storage of tools and parts. The company's parts department has a stock that includes more than 7000 items.

Each night the buses receive a safety check and each 1000 miles they are completely checked. The driver operates the same vehicle at all times, a procedure that has been found most satisfactory in preventing checking mistakes. The buses are washed every week and are periodically repainted and completely overhauled. Many economies in repair facilities have been effected by the ingenious inventions of the maintenance foremen. Quick, easy methods of pulling engines, clutches, transmissions and other major parts were described.

A disappointment of the evening was the absence of Virgil Weiss, of the Standard Oil Co., who was busy making repairs on a special lubrication demonstration car that was shown to Southern California Section members the next day at the Standard Oil Co. laboratories.

Interesting Aeronautic Meeting Ends Canadian Season

WITH an aeronautic meeting addressed by seven prominent speakers, the last gathering of the Canadian Section for the season came to a successful close at the Royal York Hotel in Toronto on Wednesday night, May 20, when Chairman Alex McArthur was able to announce that membership in the Section had doubled during the year.

Col. W. A. Bishop, V.C., D.S.O., M.C., D.F.C., Canadian war ace, who brought down 72 enemy planes, described some of his experience, emphasizing that the two main factors for success were gunnery and lots of luck. In the future, he said, the air will come to be regarded as the safest element in which to travel, having three dimensions, as opposed to two on water and one on a road. He expressed complete disbelief in airships and said that in five years the airship will be absolutely dead.

Prof. J. H. Parkin, assistant director of the Department of Physics, National Research Council of Canada, gave an interesting outline of his work in the Canadian capital, showing slides of the new equipment being built, including an air tunnel with new features and a water channel for testing floats. The former, of the atmospheric type, was to be put under test the following week.

A very interesting feature was the display by R. G. Perry, general manager of Colonial Coach Lines, Ltd., of his combination wheel and ski landing-gear for airplanes. This attracted considerable attention, and in his address Mr. Perry explained how it functions and how necessary such a device is in Canada and the Northern States where a flight might be made from snow to earth and vice versa.

A vote of thanks was accorded the three speakers on the motion of Sam Harris, president of the Canadian National Exhibition and president of the Navy League of Canada.

Oils and Oil Reclamation

TWO SPEAKERS on the subject of lubricants were heard at the May 18 meeting of the Kansas City Section, at which Chairman R. H. Van Ness presided and about 60 members and guests were present. As the Section is in a territory in which members are interested chiefly in transportation, and the speakers are well versed in their subjects and gave some valuable information, the hearers were greatly interested and took part in an extended discussion on each address.

The first speaker was L. J. Barney, lubrication engineer of the Vacuum Oil Co., who was introduced by James A. Edwards, Chairman of the Program Committee. He spoke on Lubricants and illustrated his address with lantern slides.

J. G. Sarvent, of the Sarvent Oil & Refining Co., the second speaker, gave a good talk on Oil Reclamation, which was also illustrated with slides.

Team Work in Engineering

THE importance of the engineering department to a large corporation is becoming more and more recognized by the captains of industry, and a majority of the successful companies today give engineering a high regard.

I like to think of our engineering department from the human side. The work of such an organization can be conducted in two ways: The first is the old army method, under which orders are given by a man of higher rank and strict observance of rules is required, the rank and file of the organization being kept in ignorance of the end in view. The second system, which is becoming more and more popular, is much more democratic. The organization is regarded as a team playing a game in which each individual has his part to play; the individual knows what the goal is and feels a sense of personal responsibility to work to attain it. This system may be compared with the game of football. The advantage is that a team of mediocre players may often beat a team of stars who are not trained in team play. It is the only system that will keep men working long hours or overtime to accomplish some desired result. It is the only system that will keep men loyal through the stress of the trying times at reduced salaries, never weakening or complaining. If there is any period in which engineers should stand shoulder to shoulder and pull together, it is in these trying days.

A certain spirit of freedom should be allowed to men doing brain work, giving them a sense of personal responsibility and enabling them to enjoy the feeling of satisfaction in work well done, thus inculcating an *esprit de corps* which cannot otherwise be attained. There is no ordering around in an organization of this type; the use of the pronoun "I" is noticeably absent in conversations and conferences, and men address one another by their first names. It is well worth while from an efficiency point of view alone to have the right atmosphere and environment in an organization.—From an address before the Canadian Section by H. T. Woolson, chief engineer of the Chrysler Corp.

Personal Notes of the Members

Members Elected as Officers of the N.A.T.

At a recent directors' meeting of the National Air Transport, Inc., Paul Henderson was elected chairman of its board of directors, Philip G. Johnson president and Lester D. Seymour vice-president and treasurer.

After having served in the United States Army from 1917 to 1919, Mr. Henderson held the post of Second Assistant Postmaster General, in charge of all transportation of the mail, from 1922 to 1925. The following year he became general manager of National Air Transport, Inc., and vice-president in 1928. He has been a Member of the Society since 1925.

P. G. Johnson has been president since 1926 of the Boeing Airplane Co., of Seattle, Wash., which is an Affiliate Member of the Society; president since 1927 of the Boeing Air Transport, Inc., operating the air-mail, express and passenger line between San Francisco and Chicago; president since 1928 of the Pacific Air Transport, operating a similar route between Seattle, Wash., and San Diego, Calif.; and president since 1930 of the Varney Air Lines, flying the Seattle-Salt Lake route. He is also a vice-president of the United Aircraft Transport Corp., of New York City, and a member of the board of directors of the Aeronautical Chamber of Commerce of America. The air-transport companies of which Mr. Johnson is president fly 12,000,000 miles per year. He has been an Affiliate Representative in the Society since 1919.

Mr. Seymour's membership in the Society dates from 1927. After serving in the Army Air Service in 1918 and 1919, he remained connected with that service in a consulting capacity until 1926, when he joined the National Air Transport, Inc., as chief engineer. He was promoted to the position of vice-president and general manager in 1929. A paper entitled Operation Experience of the National Air Transport, appeared in the July, 1929, issue of the S.A.E. JOURNAL, p. 217, and a personal note about Mr. Seymour was published in THE JOURNAL for September, 1928, beginning on p. 331.

Conradi Leaves Lycoming

L. C. Conradi, having resigned his position of metallurgist with the Lycoming Mfg. Co., of Williamsport, Pa., recently assumed similar duties with the International Business Machines Corp., of Endicott, N. Y. The corporation, which manufactures tabulating machines, scales and time-recording instruments, is preparing to install complete testing laboratories, which will be under the direction of Mr. Conradi.

Mr. Conradi was elected to membership in the Society in 1923 and was chief chemist of the Spicer Mfg. Corp., of South Plainfield, N. J., until 1930, when he transferred his connection to the Lycoming Mfg. Co. During the years 1928 to 1930 inclusive he was the representative of the Society on the American Society for Testing Materials subcommittee D 11 on rubber products.

Carvelli Changes to Wright

Gustaf Carvelli, after a 10-year connection with the Curtiss Aeroplane & Motor Corp., has left Buffalo and is now assistant engineer with the Wright Aeronautical Corp., of Paterson, N. J.

Mr. Carvelli joined the Society in 1921 and has been a very active member of the Buffalo Section in recent years, following his removal from Brooklyn, N. Y., with the Curtiss company to Buffalo in 1923. Before that he was a member of the Metropolitan Section. This year he is a member of the Screw-Threads Division of the Standards Committee of the Society.

From designing engineer with the Curtiss company, Mr. Carvelli became successively chief draftsman and assistant motor engineer.

Elected Bendix Aviation Directors

At a meeting of the stockholders of the Bendix Aviation Corp. on April 8, in New York City, the resignations of Frederick B. Rentschler and W. L. O'Neill were accepted and three new directors were elected, as follows: M. W. McConkey, patent attorney for Bendix Aviation Corp., of South Bend, Ind.; Charles Marcus, president of the Eclipse Aviation Corp., of East Orange, N. J.; and James C. Willson, of James C. Willson & Co., of New York City.

Mr. Marcus was also elected a vice-president of the Bendix Aviation Corp. and Walter J. Buettner was elected a vice-president in addition to treasurer.

Mr. McConkey was admitted to Associate Grade in the Society in October, 1925. He was born at Fergus Falls, Minn., in 1891 and attended George Washington University and the Washington College of Law in the City of Washington. From 1922 to 1924, he was patent attorney for the General Motors Corp., in Detroit, and in 1925 went with the Bendix Corp., in Chicago, in the same capacity.

Mr. Marcus was admitted to Member Grade in July, 1918. He was connected with the Bijur Motor Lighting Co., of Hoboken, N. J., for 10 years, rising successively from electrical engineer to chief engineer, consulting engineer and, in 1920, to vice-president of the corporation. His next connection was with the Eclipse Machine Co., of Hoboken, as manager, and in 1929 he was elected president of the company, which had moved to East Orange. He has been a member of the Metropolitan Section since 1919.

Mr. Buettner became an Associate Member in June, 1920. He was born in Chicago in 1889, and from 1909 to 1917 was private secretary with the Commonwealth Edison Co. and consulting accountant for the Chlorine Products Co. From 1917 to 1919 he was treasurer of the Air Device Co., also of Chicago. His connection with Bendix began in 1919, when he was elected secre-

PAUL HENDERSON LESTER D. SEYMOUR

tary of the Bendix Engineering Works, of South Bend, Ind. Several years later he was elected secretary and treasurer of the Bendix Corp., of Chicago. He has been a member of the Chicago Section since 1923.

Schipper and Sutton in Partnership

Having resigned as eastern manager of *Automotive Daily News*, J. Edward Schipper has gone into partnership with George W. Sutton, Jr. The new firm, known as Sutton & Schipper, will function as an industrial publicity and news-distributing organization, with offices at 232 Madison Avenue, New York City. They specialize in technical and industrial publicity accounts and the preparation of technical and semi-technical literature.

Mr. Schipper is a graduate of Webb Institute of Naval Architecture and Marine Engineering and has been associated with the automotive industry since 1911, when he became technical editor of *The Automobile*. Subsequently, when that journal became *Automotive Industries*, he was one of its engineering editors and acted as Detroit editor for this and the other Chilton Class Journal Co. publications until 1924.

In the course of that year he became eastern advertising representative for *Commercial Car Journal* and *Operation and Maintenance*. Resigning from that position in 1928, he formed the connection with *Automotive Daily News* he has just terminated.

J. EDWARD SCHIPPER

A Member of the Society since 1911, Mr. Schipper first held Section membership in the Metropolitan and later in the Detroit Section, being Chairman of the latter in 1918. As a specialist in technical writing, he contributed a number of papers on various subjects at Society meetings.

Appeal on Tariffs to President

Directors of the National Automobile Chamber of Commerce held a series of conferences with Government officials and delegates to the International Chamber of Commerce in the City of Washington during the first week in May, and on May 5 made an appeal to President Hoover for the Government to take action to prevent discrimination by foreign countries against American automobiles. The chief spokesman for the delegation received by the President was Roy D. Chapin, chairman of the board of directors of the Hudson Motor Car Co. The N.A.C.C. representatives also held conferences with Secretary of State Stimson, Secretary of Commerce Lamont and their assistants.

ROY D. CHAPIN

Other members of the Society besides Mr. Chapin who were in the delegation were Alvan Macauley, president and general manager of the Packard Motor Car Co.; Albert R. Erskine, president of the Studebaker Corp.; Charles D. Hastings, chairman of the board of directors of the Hupp Motor Car Co.; William E. Metzger, vice-president of the Federal Motor Truck Co.; and Alfred Reeves, general manager of the N.A.C.C.

At a dinner given on May 7 in honor of the foreign delegates to the conference of the International Chamber of Commerce, Mr. Reeves spoke on Trade Associations as Business Insurance.

Yanss Joins Bridgeport Brass Co.

After having served the Eastwood Wire Corp., of Belleville, N. J., for more than two years as chief engineer, where he developed the design of the company's oil strainers and a varied line of accessories and cooperated with automobile manufacturers' engineers on their application, George W. Yanss has joined the Bridgeport Brass Co., of Bridgeport, Conn., as staff engineer on the development of automotive accessories and will be contact man with engineers in the automotive industries on engineering and sales.

Prior to his Eastwood connection, Mr. Yanss was connected with the American Chain Co. in charge of the automotive accessories design division and worked closely for several years with automotive engineers on bumper and shock-absorber design and application, in which line he is regarded as an authority.

Mr. Yanss was elected to Member grade in the Society in 1920 and has been a member of both the Detroit and Metropolitan Sections. For several years he was a member of the Parts and Fittings Division of the Standards Committee and was instrumental in the standardization of bumper and shock-absorber mountings.

Gossard Now a Vice-President

Among four new officers elected at a recent meeting of the directors of the Middle West Utilities Co., of Chicago, Alvan H. Gossard was elected vice-president in charge of automotive and other transportation. He had been manager of the company's automotive department, as consultant on operation of automotive equipment, since 1927.

ALVAN H. GOSSARD

This followed a long experience in railroad and motor-truck lines.

Mr. Gossard was born in Kansas City, Mo., and, after taking the course in mechanical and electrical engineering at the University of Kansas, started commercial life as station clerk for the Kansas City Terminal Railway, and in 1912 was a special representative of the Kansas City, Mexico & Orient Railroad. The following year he joined the General Motors Truck

(*Continued on page* 44)

Gerald W. Hart

A PIONEER of modern manufacturing, Gerald W. Hart, president and founder of the Hart Mfg. Co., of Hartford, Conn., passed away on March 8.

Mr. Hart, who was born in July, 1856, at New Britain, Conn., studied mechanical engineering at the Sheffield Scientific School of Yale University. From 1880 to 1887 he was employed by the American Electric Co., which later became the Thomson-Houston Electric Co., and during the next three years was connected, in turn, with the Edison Electric Light & Power Co. and then with the Kansas City Electric Light Co., both of Kansas City, Mo., as assistant manager and superintendent. He organized the Hart & Hegeman Mfg. Co., of Hartford, Conn., in 1890, which eight years later became the Hart Mfg. Co., makers of electric switches.

In November, 1917, Mr. Hart was elected a Member of the Society.

William Tully Norton

NOTIFICATION has been received of the death of William Tully Norton at his home in Lakewood, Ohio, on April 28.

Mr. Norton was admitted to Member grade in the Society in 1911 and was also a member of the American Society of Mechanical Engineers. He was born at Cleveland in 1880 and received his technical education at the Case School of Applied Science in that city. All of his professional life was devoted to the automotive industry. In 1902 he was engaged in drafting for the General Automobile Co., of Cleveland; from 1903 to 1906 he was doing designing and general experimental work under Howard E. Coffin for the Olds Motor Works, in Detroit; and during the following 12 years was successively designer for the Aero Car Co., superintendent of the Kansas City Motor Car Co., chief inspector of the Chalmers Motor Co., and experimental engineer of James Cunningham, Son & Co. and of the Selden Motor Truck Co., of Rochester, N. Y.

During the World War Mr. Norton spent six months in 1916 in England and France checking the performance of motor-trucks under war conditions. He was then chosen a member of a committee of engineers from truck companies to pass on the design of Class A and Class B Army trucks for use on the Mexican border and which subsequently cooperated with the War Department in drafting revised specifications for standardized trucks for the World War. In seven days after receiving the final specifications for the Class B truck, Mr. Norton completed the first one at the Selden factory and drove it himself to Washington, where he delivered it to Colonel Baker.

In 1919 Mr. Norton returned to France as technical adviser to the chief of the Motor Transport Corps, American Expeditionary Force, and for four years thereafter was assistant chief of the engineering branch of the Corps, stationed successively at Washington, Camp Holabird, Md., and Lakewood, Ohio.

Since 1923 Mr. Norton had been chief engineer of the L. M. Axle Co., of Cleveland, and the Sarasin Six-Wheel Truck Co., of Haverhill, Mass.; and in the last five years was engaged in private consulting work.

Walter R. Shaw, Jr.

THE FATHER of Walter R. Shaw, Jr., has notified the Society, with great regret and sorrow, that his son, who was recently elected a Junior Member, was shot on March 6 by a highwayman in St. Louis while grappling with him in an effort to resist robbery. Although Mr. Shaw, Jr., made a valiant fight for life in the hospital, he passed away on April 14, before receiving the notification of his election to membership.

Mr. Shaw was a special representative of the Pennsylvania Crude Oil Association, of Oil City, Pa., and was engaged in giving talks on refinery technology, production, and the desirability of supplying oils marketed under the Association emblem. He was born at Rochester, N. Y., in 1908, and prior to accepting the position with the Association in March, 1930, had been connected for more than two years with the Kendall Refining Co., first in general laboratory work and later as control chemist, doing special work on Sligh oxidation tests and other problems outside of control work.

James N. Heald

AFTER having been in failing health for some time, heart trouble ended the notable career of James N. Heald, president and general manager of the Heald Machine Co., of Worcester, Mass., at his home in that city on May 6, to the great sorrow of his family, friends and associates.

Mr. Heald, who had been a Member of the Society for the last 20 years, was born in Barre, Mass., in 1864 and received the degree of Master of Science from the Worcester Polytechnic Institute. He then entered the family firm of S. Heald & Son, in Barre, as superintendent and designer. Later he became a partner in the business and in 1903 bought out his father's interest and organized the Heald Machine Co., of Worcester. In the earlier years he invented and designed the American drill-grinder, the Heald dado machine, the Heald crimping machine and the American sash trimmer, and in the later years concentrated his efforts on grinding machines, including center grinders, ring and surface grinders, internal grinding-machines and magnetic chucks for holding the work.

For many years Mr. Heald was a member of the National Machine Tool Builders Association, serving for three years on the board of directors and at one time being treasurer. He was also a member of the American Society of Mechanical Engineers, the Worcester Chamber of Commerce, the Worcester County Mechanics Association and the Alumni Association of Worcester Polytechnic Institute. He was a director of the Worcester Bank & Trust Co. and a trustee of the Peoples Savings Bank.

William LeRoy Bryant

WITH great regret the Bryant Chucking Grinder Co., of Springfield, Vt., reported the sudden death on April 25 of its president, William LeRoy Bryant.

Mr. Bryant was one of the most prominent machine-tool manufacturers in the Country, as he had made outstanding contributions to the industry, including the suspended-wheel slide control which has been applied to semi-automatic and full-automatic grinding-machines of various types. He was also the inventor of the Bryant chucking grinder.

Born at Northfield, Vt., in 1875, Mr. Bryant received his education in electrical engineering at the University of Vermont and in 1897 started his professional career with the Jones & Lamson Machine Co., of Springfield, Vt. He continued this connection for 12 years, engaged in designing machine-tools, jigs, fixtures, turret-lathe equipment and in structural engineering, and became chief engineer of the company. In 1909 he left the Jones & Lamson company to form the Bryant Chucking Grinder Co., of which he was president and manager.

Mr. Bryant was elected to Member Grade in the Society in 1921 and was also a member of the American Society of Mechanical Engineers, a director of the Associated Industries of Vermont and a director of the First National Bank of Springfield.

Louis Cassinelli

INFORMATION has been received from the Wilcolator Co., of Newark, N. J., of the death on March 26 of Louis Cassinelli, the company's chief inspector and test engineer, who was in charge of development work.

Mr. Cassinelli had been connected with the automotive industry from the pioneer days of the automobile in this Country and had been an Associate

Member of the Society for 16 years, having been elected in January, 1914.

Born in Italy in 1881, his first connection with the industry in America was with the old Gasmobile Co. of America, at Marion, N. J., with which he remained for three years, working in all of the mechanical departments. Then for one year he was with the Fisher System, in Hoboken, N. J. From 1906 to 1915 he was foreman and superintendent of the Twombly Motor Co., in New York City, engaged in developing and constructing automobiles, engines and cyclecars. Successively thereafter he became superintendent of the Slessinger & Redburn Corp.; foreman of the laboratory of the Acme Accessories Corp., supervising the development of gasoline vacuum and pressure-feed pumps; assistant to the general foreman of the Wright-Martin Aircraft Corp., in 1918; superintendent of the laboratory of the United Motors Corp. and later the Klaxon branch of the General Motors Corp. in Newark, N. J., in 1919; and in 1920 joined the H. A. Wilson Co., of Newark, in the same capacity, supervising development and design work on thermostats for ranges and boilers. He retained this connection for the last 11 years.

Thomas J. Wetzel

THROUGH the passing away of Thomas J. Wetzel at his apartment in the Woodward Hotel in New York City on April 23, the industry has lost one of its prominent members who had been identified with it for the last 30 years, ever since there was an automobile business in this Country. The Socety has also lost a member of 20 years' standing, as Mr. Wetzel was admitted as an Associate Member in January, 1911.

He had always been in the commercial branch of the industry, having been, at the time of joining the Society, manufacturers' selling agent in the eastern territory for the Brown-Lipe Gear Co. for 10 years, the Spicer Mfg. Co. for 6 years and the Whitney Mfg. Co. and the Pittsfield Spark Plug Co. for 5 years each. He continued in this work up to the time of his death, maintaining offices in West 57th Street, New York City, since 1921. In 1928 he organized and was elected president of the Wetzel-Fraser Co., which established headquarters in the General Motors Building in Detroit, and in 1929 he became general manager of the Thomas J. Wetzel Co., which opened offices in the Fisher Building in Detroit. During all this time he continued as owner of his sales agency in New York.

Mr. Wetzel was born at Dayton, Ohio, in June, 1867. Besides holding membership in the Society, he was a member of the New York Athletic Club, the Detroit Athletic Club and the Siwanoy Country Club.

Applicants for Membership

The applications for membership received between April 16 and May 16, 1931, are listed below. The members of the Society are urged to send any pertinent information with regard to those listed which the Council should have for consideration prior to their election. It is requested that such communications from members be sent promptly.

BARKER, FREDERIC R., engine designer, Lycoming Mfg. Co., *Williamsport, Pa.*

BARTON, CYRIL HENRY, chemist, Asiatic Petroleum Co., *London, E. C. 3, England.*

BLODGETT, GEORGE R., engineer, Moto-Meter Gauge & Equipment Corp., *Toledo, Ohio.*

BOWERS, W. T., foreman, automobile maintenance, William Schluderberg, T. J. Kurdle Co., *Baltimore.*

BUEHRIG, GORDON MILLER, body designer, Duesenberg, Inc., *Indianapolis.*

BURCKHALTER, R. N., engineer, Michiana Products Corp., Sheet Steel Division, *Michigan City, Ind.*

CADWELL, SIDNEY M., director, development division, United States Rubber Co., *Detroit.*

CHAMBERS, GEORGE N., service superintendent, The White Co., *Wilkes-Barre, Pa.*

CHENEY, MOSES EDWARD, chief engineer, Moto-Meter Gauge & Equipment Corp., *Toledo, Ohio.*

EISENBEIS, GEORGE G., draftsman, Lycoming Mfg. Co., *Williamsport, Pa.*

ELLIS, WILLIAM B., supervisor, waste collection division, City of Cincinnati Public Works Department, *Cincinnati.*

GARNSEY, EVERETT N., research laboratory, testing fuels, Ethyl Gasoline Corp., *Yonkers, N. Y.*

GERHARDT, WILLIAM FREDERICK, professor of aeronautical engineering, College of City of Detroit, *Detroit.*

GILCHRIST, SYDNEY E., service manager, Welch & Johnston, Ltd., *Ottawa, Ont., Canada.*

HACKER, JOHN E., experimental superintendent, White Motor Co., *Cleveland.*

HASKELL, A., sales, Calumet Refining Co., *Chicago.*

HELM, LOGAN B., superintendent, lubricating plant, manufacturing department, Standard Oil Co. (Ohio), *Cleveland.*

HEMKE, PAUL E., associate professor, Post Graduate School, United States Naval Academy, *Annapolis, Md.*

HIGGINS, GEORGE JUDSON, associate professor in aeronautical engineering, University of Detroit, *Detroit.*

HOOVER, WILLIAM P., designer and estimator, American Bearing Corp., *Indianapolis.*

HOWARD, HARRY BUCKNER, research chemist, New Orleans Public Service, Inc., *New Orleans.*

KNOHL, KARL, designer, Maccar Truck Co., *Scranton, Pa.*

KNOTT, ERNEST WALTER, assistant chief engineer, Stromberg Motor Devices, Ltd., *Birmingham, England.*

MCKENZIE, CHARLES SIDNEY, general superintendent, Ontario Steel Products Co., Ltd., *Gananoque, Ont., Canada.*

MCMANN, WILLIAM J. R., general automobile repairing, 170 East 94th Street, *New York City.*

MIANO, N. J., eastern district manager, Ralph N. Brodie Co., *Oakland, Calif.*

MITTELMAN, LOUISE, radio and battery manufacturing, Philadelphia Storage Battery Co., *Philadelphia.*

OBERG, WILLIAM C., manager, roll and hoop department, Carnegie Steel Co., *Pittsburgh.*

OTT, LUTHER A., head of department of aeronautical engineering, Tri-State College, *Angola, Ind.*

PEARSON, HAROLD CHARLES, sales manager, Dewey & Almy Chemical Co. of Canada, Ltd., *Farnham, Que., Canada.*

RAABE, H. LEROY, instructor of automobile mechanics, Department of Education, *Baltimore.*

RESWICK, MAURICE, mechanical engineer, Pennsylvania Lubricating Co., *Pittsburgh.*

RUE, ORLIE, superintendent, transmission and distribution, Central Illinois Public Service Co., *Springfield, Ill.*

SCHULTZ, EUGENE CHARLES, engineer, New Orleans Public Service, Inc., *New Orleans.*

SESSIONS, EDSON OLIVER, industrial engineer, Bendix Aviation Corp., *South Bend, Ind.*

SMITH, HERBERT H., draftsman, International Harvester Co., *Fort Wayne, Ind.*

STODDARD, ROBERT W., assistant manager, aviation division, Wyman-Gordon, Co., *Worcester, Mass.*

SWAHNBERG, GUNNAR, chief engineer, Kingsbury Machine Tool Corp., *Keene, N. H.*

TAYLOR, GAVIN R., chief chemist, McColl-Frontenac Oil Co., Ltd., *Montreal, Que., Canada.*

TAYLOR, H. B., superintendent of maintenance, American Airways, Inc., Love Field, *Dallas, Texas.*

UNDERWOOD, RICHARD L., patent lawyer, Parker & Burton, *Detroit.*

VIADAS, ERNESTO, advising engineer, machinery department, Comisien Nacional de Caminos, *Monterey, Mexico.*

WASHBURN, CLARENCE L., junior engineer, mechanical and tool designer, Westinghouse Electric & Mfg. Co., *Chicopee Falls, Mass.*

WELLMAN, CHARLES E., automotive engineer, Ford Motor Co., *Dearborn, Mich.*

WELTE, BENEDICT, machine designer, Kearney & Trecker, *Milwaukee.*

WETTSTONE, JOHN MILTON, field maintenance man, Standard Oil Co., *Cleveland.*

WHISTLER, JOHN M., first lieutenant, Field Artillery, U.S.A., *Fort Sill, Okla.*

WIJEYERATNE, PATRICK DE SILVA, engineer, Colonial Motors & Engineering Co., Ltd., Union Place, *Colombo, Ceylon.*

WOLF, FRED L., chief engineer and technical superintendent, Ohio Brass Co., *Mansfield, Ohio.*

WORKMAN, JAMES H., first lieutenant, Field Artillery, U.S.A., *Fort Sill, Okla.*

WRIGHT, GEORGE W., superintendent, garage department, Toronto Transportation Commission, *Toronto, Ont., Canada.*

Applicants Qualified

The following applicants have qualified for admission to the Society between April 10 and May 10, 1931. The various grades of membership are indicated by (M) Member; (A) Associate Member; (J) Junior; (Aff.) Affiliate; (S M) Service Member; (F M) Foreign Member.

BELL, GODFREY WILLIAM (F M) consulting motor engineer, *Melbourne, Victoria, Australia;* (mail) Oronsay, 21 Brenbeal Street, Balwyn.

BLACKMER, W. H. (M) sales manager, Laminated Shim Co., Inc., 21 to 24 44th Avenue, *Long Island City, N. Y.*

BRAUER, ARTHUR C. (M) design checker, General Motors Export Corp., *Detroit;* (mail) 1691 West Euclid Avenue.

BROWN, RAY WALTER (A) regional aviation representative, Shell Petroleum Corp., 624 South Michigan Avenue, *Chicago.*

BUTERA, CHARLES N. (J) student, training course, mechanical engineer, Kings County Buick, Inc., Brooklyn, N. Y.; (mail) 7 Ann Street, *Morristown, N. J.*

CHAPPELL, FRANK (M) factory manager, General Motors of Canada, Ltd., *Oshawa, Ont., Canada.*

CHARLESWORTH, THOMAS RICHARD (F M) chief draftsman, Laycock Engineering Co., Ltd., *Sheffield, England;* (mail) 115 Brookhouse Hill, Fulwood.

COREY, L. A. (A) secretary and treasurer, Northern Engraving & Mfg. Co., Fourth and Vine Streets, *La Crosse, Wis.*

COULTER, E. M. (J) mechanic, Equitable Auto Co., Pittsburgh; (mail) 853 Rebecca Avenue, *Wilkinsburg, Pa.*

DAVIS, W. RALPH (A) assistant general superintendent, Houston Electric Co., Box 1288, *Houston, Tex.*

DEAN, W. B. (J) test and development engineer for Hele-Shaw transmissions, American Engineering Co., Aramingo Avenue and Cumberland Street, *Philadelphia.*

DOYING, W. A. E. (S M) inspecting engineer, chief inspector, Panama Canal, *City of Washington.*

EDENQUIST, GUNNAR (M) designer, Kinner Airplane & Motor Corp., 635 West Colorado Boulevard, *Glendale, Calif.*

EDWARD, CHARLES KEMP (A) purchasing agent, Durant Motors of Canada, Ltd., *Toronto, Ont., Canada;* (mail) 72 Rowanwood Avenue.

ELLIS, GEORGE (F M) consulting automobile engineer, 134 Burwood Road, *Concord, New South Wales, Australia.*

FAIRCHILD, HAROLD WELCH (J) assistant aeronautical engineer, United Aircraft & Transport Corp., Research Division, East Hartford, Conn.; (mail) 373 Farmington Avenue, *Hartford, Conn.*

FARMER, GEORGE (A) operating engineer, Illinois Power & Light Corp., 542 South Adams Street, *Peoria, Ill.*

GATELY, M. J. (A) assistant to first vice-president, American Oil Co., American Building, *Baltimore.*

GRACCHI, CELESTINO LOUIS (J) stress analyst, Keystone Aircraft Corp., *Bristol, Pa.;* (mail) 1616 Farragut Avenue.

GREEN, HERBERT FRANKLIN (J) mechanical engineer, Ethyl Gasoline Corp., Yonkers, N. Y.; (mail) 551 West 170th Street, *New York City.*

GREEN, JERRY O. (M) chief chemist, Standard Oil Co. of New Jersey, *Baltimore;* (mail) P. O. Box 104, Highlandtown, Station.

GRIERSON, C. I. (M) president, Transport Oil, Ltd., D. A. Stuart & Co., Ltd., *Toronto, Ont., Canada;* (mail) 50 Garfield Avenue.

HENNINGER, ANTHONY A. (M) president, general manager, New Process Gear Co., Inc., 500 Plum Street, *Syracuse.*

HILLBORN, HERBERT J. (M) mechanical engineer, Koehring Co., 31st Street and Concordia Avenue, *Milwaukee.*

HORLE, JOSEPH FREDERICK (F M) manager, Motor Services (London), Ltd.; (mail) 46 Emlyn Road, Stamford Brook, *London W. 6, England.*

KEMP, JAMES ALEXANDER (F M) chief draftsman, Maudslay Motor Co., Ltd., *Conventry, England;* (mail) 76 Stoneleigh Avenue.

LAWLOR, JOHN CORNELIUS (A) 5134 Gatineau Street, *Montreal, Que., Canada.*

LEVEAU, WALTER (J) chief designer, Horace E. Dodge Boat & Plane Corp., *Newport News, Va.*

LITTLE, LESLIE FRANCIS (F M) chief draftsman, Vickers-Armstrong, Ltd., Garden-Loyd Tractors Department, *Chertsey, Surrey, England;* (mail) Cornerways, Weir Road.

LITTLEFIELD, ALTON H. (S M) inspector, United States Army, Quartermaster Corps (Motor Transport), Co. A, First Motor Repair Battalion, *Camp Holabird, Baltimore.*

LOVESETH, ENOCH L. (A) president, manager, Loveseth Service Station, Ltd., Jasper Avenue at 106th Street, *Edmonton, Alta., Canada.*

LOWE, WILLIAM W. (M) chairman of manufacturing committee and assistant chief technologist, Henry L. Doherty & Co., 60 Wall Street, *New York City.*

LYBECK, ROBERT F. (M) manager, wholesale gasoline and motor oil sales, Colonial Beacon Oil Co., Inc., 20 Providence Street, *Boston.*

MARTIN, FRANK H. (A) general salesman, assigned to lubrication, Standard Oil Co., *El Centro, Calif.*

MCKEE, S. M. (A) superintendent, lubricating engineer, Nourse Oil Co., *Kansas City, Mo.;* (mail) 4456 Francis Street.

MEUWLY, FELIX HARRY (J) electrician, Missouri Pacific Transportation Co., *Little Rock, Ark.;* (mail) 3105 West 15th Street.

MORGAN, WILLIAM C., JR. (A) sales engineer, Oldberg Mfg. Co., 2667 East Grand Boulevard, *Detroit.*

NOONAN, EDMUND L. (A) military service engineer, Curtiss Aeroplane & Motor Co., *Buffalo.*

PAWSON, FREDERICK (A) assistant to technical service engineer, General Motors Products of Canada, Ltd., *Oshawa, Ont., Canada;* (mail) Genosha Hotel.

PHILLIPS, BERNARD C. (J) engineer, Tillotson Mfg. Co., *Toledo, Ohio;* (mail) 5825 Foth Drive.

RITCHIE, DANIEL F. (J) equipment sales engineer, Allis-Chalmers Mfg. Co., *Springfield, Ill.;* (mail) 925 Bryn Mawr Boulevard.

RITTER, HAROLD J. (A) assistant secretary, Norma-Hoffmann Bearings Corp., *Stamford, Conn.;* (mail) 14 Pierce Place.

SARTELL, PAGE M. (M) assistant mechanical engineer, aeronautical engine laboratory, League Island Navy Yard, Philadelphia; (mail) 30 Kent Road, *Upper Darby, Pa.*

SNYDER, W. OVERTON (M) division engineer, in charge of maintenance, Caribbean division, Pan American Airways, Inc., 44 Biscayne Boulevard, *Miami, Fla.*

STEWART, CURTIS C. (A) sales engineer, Lapeer-Trailmobile Co., 2707 South Michigan Boulevard, *Chicago.*

STRATFORD, FRED (A) president, Fred Stratford, Ltd., 17 Elm Street, *Toronto, Ont., Canada.*

TESTONI, FELICE ARMANDO (F M) general manager, Societa Anonima Lepto, *Varese, Italy;* (mail) Via Sempione No. 20.

VAHEY, STANLEY (J) sheet-metal and body designer, Chevrolet Motor Car Co., Detroit; (mail) 224 Gray Court, *Birmingham, Mich.*

VALLINGS, GEOFFREY HAROLD (F M) chief assistant motor engineer, Shell Mex, Ltd., London, England; (mail) Desmond, Parkland Crescent, *Ashford, Middlesex, England.*

WIEBEN, HERMAN C., JR. (J) design draftsman, stress analyst, Keystone Aircraft Corp., Bristol, Pa.; (mail) 1144 Clay Avenue, *New York City.*

WILLIAM, ESPY W. H. (J) statistician, Automotive Trades Alliance, division of Automotive Service Bureau, 210 South Hanover Street, *Baltimore.*

WINKLER, ALBERT HERMAN, JR. (J) experimental engineer, Bendix Stromberg Carburetor Co., *South Bend, Ind.;* (mail) 1510 Lincoln Way, West.

WITTLINGER, LEONARD M. (M) engineer, motor division, engineering department, Buick Motor Co., *Flint, Mich.*

WITTER, ERNEST J. (A) Cleveland district service manager, White Motor Co., 7821 St. Clair Avenue, *Cleveland.*

Notes and Reviews

AIRCRAFT

Strength Tests on Paper Cylinders in Compression, Bending and Shear. By Richard V. Rhode and Eugene E. Lundquist. Technical Note No. 370; 14 pp., 31 figs. [A-1]

Experiments with an Airfoil Model on Which the Boundary Layer Is Controlled without the Use of Supplementary Equipment. By I. H. Abbott. Technical Note No. 371; 6 pp., 5 figs. [A-1]

Preliminary Study of Applied Load Factors in Bumpy Air. By Richard V. Rhode and Eugene E. Lundquist. Technical Note No. 374; 30 pp., 6 figs. [A-1]

Moments of Inertia of Several Airplanes. By Marvel P. Miller and and Hartley A. Soulé. Technical Note No. 375; 6 pp., 1 fig. [A-1]

The foregoing four Technical Notes were issued during April and May, 1931, by the National Advisory Committee for Aeronautics, City of Washington.

A Study of Curvilinear Flight. By Helmuth Kruse. Translated from *Zeitschrift für Flugtechnik und Motorluftschiffahrt*, Jan. 28, 1931, vol. 22, no. 2; Verlag von R. Oldenbourg, München und Berlin. Technical Memorandum No. 615; 22 pp., 15 figs. [A-1]

Aeronautical Education and Research at the Swiss Institute of Technology in Zurich. By L. Karner and J. Ackeret. Translated from *Aero-Revue*, Nov. 15, 1930. Technical Memorandum No. 616; 8 pp., 2 figs. [A-1]

Investigation of Certain Wing Shapes with Sections Varying Progressively along the Span. By L. Arsandaux. Translated from *L'Aéronautique*, March, April and May, 1928. Technical Memorandum No. 617; 44 pp., 15 figs. [A-1]

Relative Economy of Different Methods of Airplane Construction. By H. Herrmann. Translated from *Zeitschrift für Flugtechnik und Motorluftschiffahrt*, Nov. 14 and 28, 1930; Verlag von R. Oldenbourg, München und Berlin. Technical Memorandum No. 618; 43 pp., 18 figs. [A-1]

Determination of Resistance and Trimming Moment of Planing Water Craft. By P. Schröder. Translated from *Zeitschrift für Flugtechnik und Motorluftschiffahrt*, Nov. 28, 1930; Verlag von R. Oldenbourg, München und Berlin. Technical Memorandum No. 619; 8 pp., 9 figs. [A-1]

These items, which are prepared by the Research Department, give brief descriptions of technical books and articles on automotive subjects. As a rule, no attempt is made to give an exhaustive review, the purpose being to indicate what of special interest to the automotive industry has been published.

The letters and numbers in brackets following the titles classify the articles into the following divisions and subdivisions: *Divisions*—A, Aircraft; B, Body; C, Chassis Parts; D, Education; E, Engines; F, Highways; G, Material; H, Miscellaneous; I, Motorboat; J, Motorcoach; K, Motor-Truck; L, Passenger Car; M, Tractor. *Subdivisions*—1, Design and Research; 2, Maintenance and Service; 3. Miscellaneous; 4, Operation; 5, Production; 6, Sales.

The foregoing five Technical Memoranda were issued during April and May, 1931, by the National Advisory Committee for Aeronautics, City of Washington.

Portances Elevées et Profils Hypersustentateurs. By Fr. Haus. Published in *L'Aéronautique*, April, 1931, p. 125. [A-1]

In dealing with high-efficiency wings, the author, chief of the Belgian aeronautical service, first presents the aerodynamic phases of the subject. He points out that all such wing types, while differing in form, rely fundamentally on one expedient; that is, increasing the air-flow.

He discusses briefly variable-area and variable-camber wings, but concentrates his attention particularly on the prevention of burbling. This is the phenomenon, he says, which places a limitation on increasing the angle of incidence as a means for increasing lift. While experiments have been made with independent means of increasing air-flow, he believes that the most fertile field for improving lift characteristics lies in the development of means for preventing burbling. These will afford practicable solutions that can be adapted to airplanes without necessitating any radical modification in them. In a future article he will made a detailed study of burble prevention.

Der Einfluss des Holmgewichtes auf die Bauspannweite und die Flugleistungen von Grossflugzeugen. By E. v. Lössl. Published in *Zeitschrift für Flugtechnik und Motorluftschiffahrt*, March 28, 1931, p. 157. [A-1]

In this article the influence of wing-spar weight on wing span and on the flight characteristics of large aircraft is theoretically treated. Only centrally loaded wings are considered, as, while load distribution is advantageous in general, the central loading brings important benefits in the cases of military craft and flying-boats.

First, wing-spar weight is analyzed and comparisons made between the internally and externally braced types. Calculated spar weights for different wing loadings for a given wing span are given. Various factors affecting wing span are next considered and weighed in the determination of the most favorable wing span. This question is thought to be of theoretical interest only in the case of the small airplane, since the optimum wing span is too great to be used in actual construction, but is, in the author's opinion, of more practical moment in the case of larger types. The flight characteristics of two airplanes, one large and the other small, both having internally braced wings and the span previously determined as the optimum, are presented and contrasted.

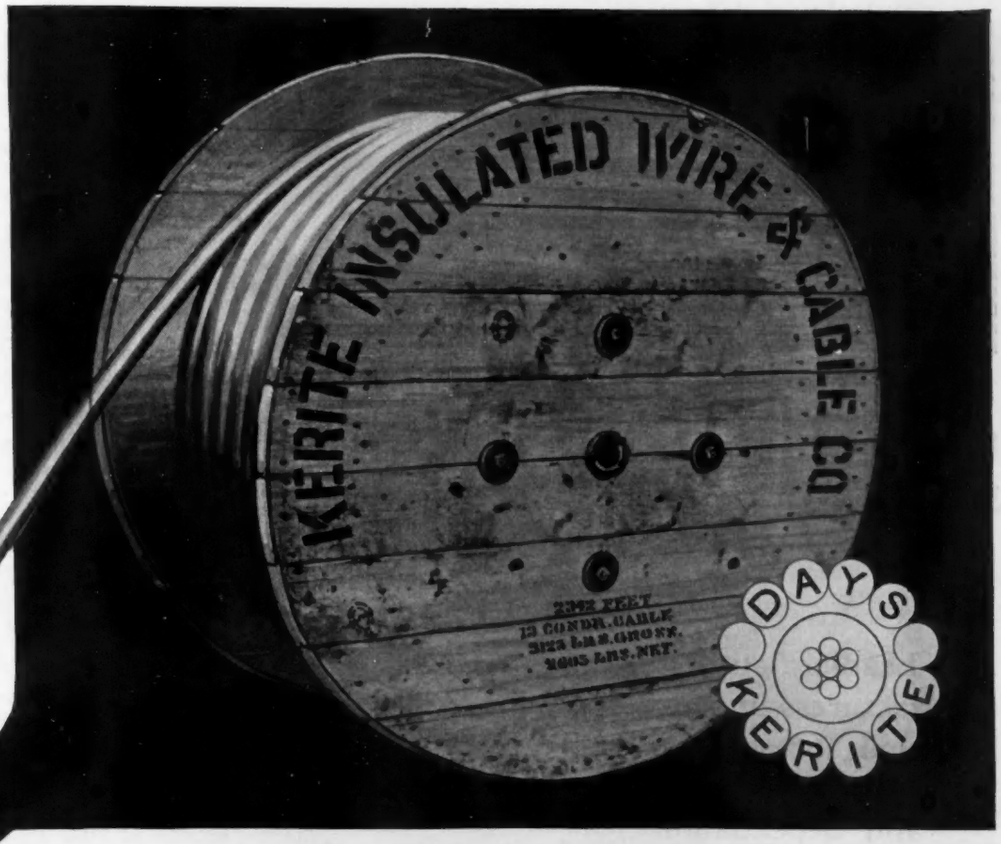
Messung der Sicht von Führersitz Verschiedener Flugzeugmuster. By Gerhard Kurz. Published in *Zeitschrift für Flugtechnik und Motorluftschiffahrt*, March 28, 1931, p. 167. [A-1]

To substitute actual measurements of the field of vision from the pilot's seat of an aircraft for empirical judgment was the object of the research carried out by the German institute for aeronautical research which is reported in this article.

The instruments developed for the purpose are described, as are also measurements made with them. The field of vision from six airplanes differing in construction and type was measured, and for purposes of comparison the same determination was made for the driver's seat of an automobile. Various methods of representing the field of vision are shown and their usefulness for different purposes is pointed out. The results of the measurements are compared with photographs of the field of vision and an attempt is made to fix the minimum requirements and the basis for assigning a merit figure to types of outlook obtained from the cockpit.

Berechnung der Auftriebsverteilung Beliebig Geformter Flügel. By Irmgard Lotz. Published in *Zeitschrift für Flugtechnik und Motorluftschiffahrt*, April 14, 1931, p. 189. [A-1]

(*Continued on next left-hand page*)



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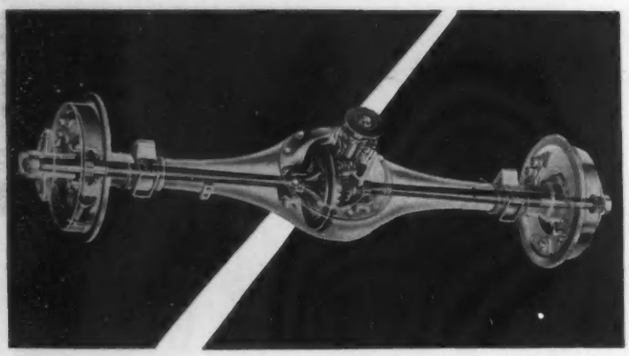

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PARISH FRAMES and STAMPINGS — PARISH PRESSED STEEL CO. READING PENNA.

Notes and Reviews

Continued

Part 1 of this article contains a review of the method commonly used for calculating lift distribution over a wing surface. In Part 2 a method based on the use of Fourier series is developed and applied to a given profile and a given variable angle of attack. Part 3 presents formulas for rolling and yawing moments and a comparison of the calculated results with those obtained in previous investigations.

The Aircraft Yearbook for 1931. Compiled by the Aeronautical Chamber of Commerce of America, Inc.; published by D. Van Nostrand & Co., Inc., New York City; 670 pp., including index. Profusely illustrated with photographs, maps, charts and diagrams. **[A-3]**

Contrary to prevailing assumption, vol. 13 of The Aircraft Yearbook, compiled, written and edited by the Aeronautical Chamber of Commerce of America, is the best volume that has been sponsored by the Chamber. Physically, it is a good piece of book-making and, aside from some changes that could be made typographically in the design, engine, and appendix sections, it will make an attractive addition to any engineer's library. Its 19 chapters cover American aeronautic activities thoroughly. Retaining the prophetic first chapter and other desirable chronological characteristics of the first volume, The Aircraft Yearbook has become indispensable to organizations and individuals desiring to keep up with happenings in aviation. It is the "world's almanac" of flying.

While the editorial material is colored by the commercial aspects of the business, and many facts are given undue prominence because of this, the annual survey is accurate and well-proportioned otherwise. It is fortunate that the industry has had, so early in its growth, a coordinating body with a vision of the value of a record of genealogical progress.

The book's substance matter covers the aeronautic history of 1930 with predictions for 1931, aeronautic traffic in America and Latin America, projected world airship-services, the work of the Army and the Navy, epic-making flights, a survey of American aircraft and engine-manufacturing activities, certain commercial aspects, air terminals on land and sea, flying schools, male and female pilots, and aviation laws, research, and general world progress. In addition there are the usual aircraft and engine-design sections, a chronology containing day-to-day accounts of important happenings, a well digested appendix and a trade index.

CHASSIS PARTS

Calculating Front-Axle Stresses by Practical Method Supplies Data Quickly. By K. W. Najder. Published in *Automotive Industries*, Mar. 14, 1931, p. 443. **[C-1]**

The author points out that calculation of stresses in machinery parts is incomplete unless the engineer knows from experience what factors of safety are necessary. Selection of the right material also is important, as are the hardness of the material and its minimum elastic limit, on which latter all factors of safety should be based. The time factor is of prime importance in all calculations, he contends, because usually the engineer is required to supply the information quickly and must be able also to quickly revise his calculations for certain changes that may be found desirable during the progress of the design work. The author therefore presents the calculations from the practical side, giving also factors of safety, suitable materials and their hardnesses.

Schwingungen in Automobillenkungen. By Gabriel Becker, Hans Fromm and Herbert Maruhn. Published by M. Krayn, Berlin; 150 pp.; 118 illustrations. **[C-1]**

A comprehensive investigation of shimmy is covered in this report. Both analytical and experimental methods were

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Nash Eight
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De Soto Six
Chrysler Imperial
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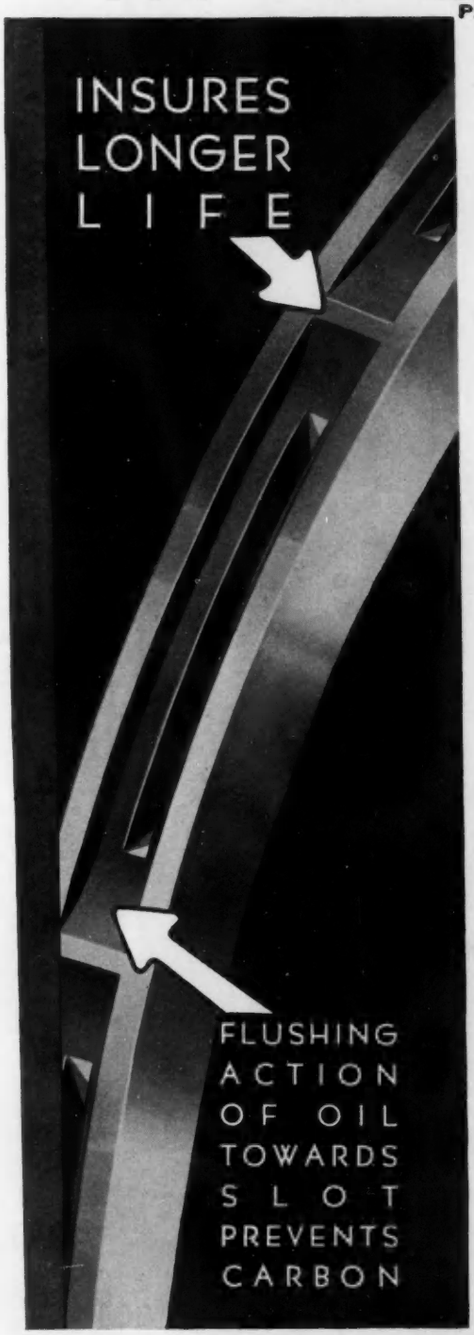
De Vaux
Willys Knight
Buda Motors



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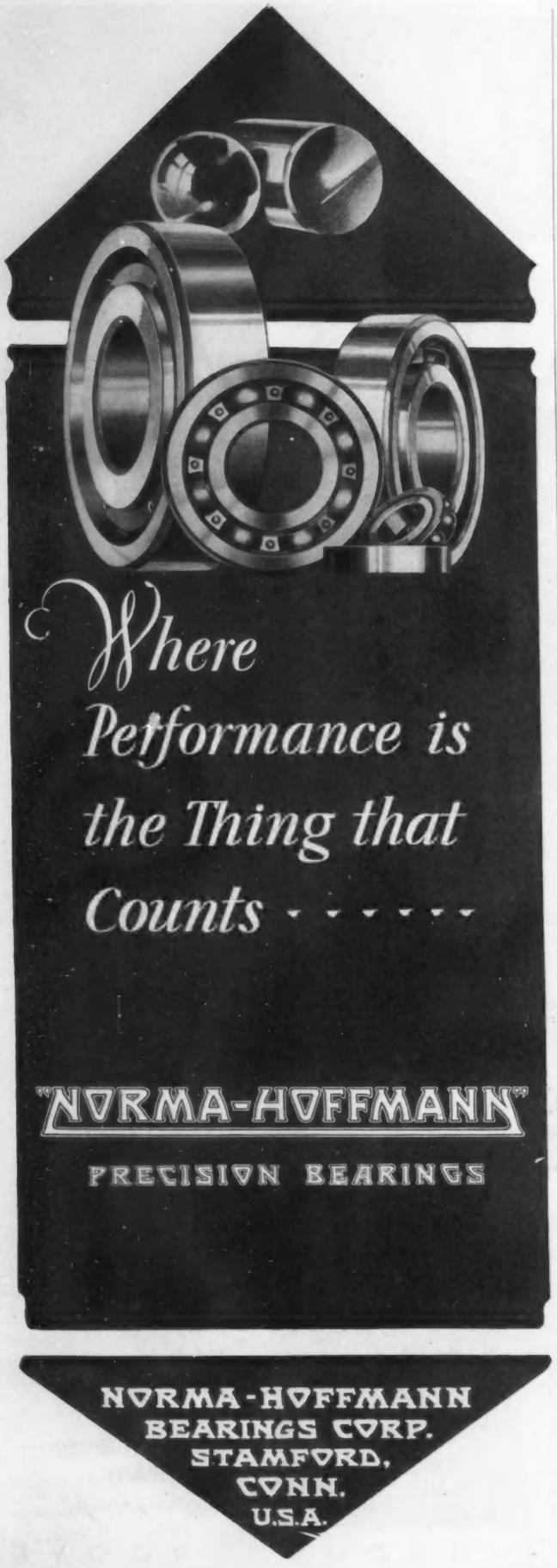

Notes and Reviews

Continued

applied and all parts of the steering system and front-axle assembly were studied in the effort to present a unified inclusive picture of the causes and manifestations of shimmy. Gabriel Becker, director of automotive research for the Berlin Technical University, conceived the plan, in the execution of which he was aided by his associate, H. Maruhn, and by H. Fromm, director of the materials-testing laboratory. The research was carried out in the laboratories of the university with the financial assistance of the German government.

The first part presents a study of the front axle and the steering linkage as a vibrating system. The second section sets forth the fundamental theories of vibration, its causes, amplitudes, frequencies and interdependences. In the third section the extensive experimental research is recorded. All elements of the front-axle assemblage contributing to shimmy, such as springs, tires, wheels and steering-system linkage, were studied, as was also the influence of elasticity, inertia moments, weight and other factors entering into the phenomenon.

From analysis of the results obtained in the experimental work, the conclusion is drawn that the trapezoidal form of steering-system linkage is an insurmountable obstacle to the conquest of shimmy; and in the fourth section a new steering device employing a type of cross-linkage is described and analyzed. This device is said to compensate the gyroscopic moments of the front wheels, and this compensation has been shown by tests to result in a very considerable decrease in the vibrations caused by unbalanced wheels, low-pressure tires and steering-system elasticity.

A theory of front-axle vibration is presented in Part 5 and several examples are worked out.

Manufacturing Gears for Continued Accuracy. By A. B. Cox. Published in *American Machinist*, Mar. 26, 1931, p. 500. **[C-5]**

The gear problem has two parts: to make the gear accurate and to make it so that it will remain accurate for a reasonable time. The first part has been given too much attention in some respects to the neglect of the other, the author contends.

In a somewhat detailed survey of gear-production methods, the author considers, from a point of accuracy, the formed-cutter method, the generating method, and the practice of grinding back to the scrapping point.

Mr. Cox points out that little uniformity of practice exists among manufacturers whose products require accurate gears. Automobile builders, for the most part, are said to use gear-shaping machines, while others make special hobbing machines or work over a standard machine to eliminate as many errors as possible.

Eccentricity or other tooth-contour irregularities in any of the gears of the train connecting the hob and work-table will cause irregular rotation of hob and table with respect to each other, and a correct tooth form cannot be generated. Hence the first essential in hobbing accurate gears is to have accurate gears in the hobbing machine itself. Equally important is the reducing of backlash and lost motion. Contrary to the belief of some operators, centering the hob on the gear blank does not and cannot avoid this difficulty. Flywheels used in attempts to steady the motion of hob and table are often incorrectly applied. The principles of torsional vibration applied in internal-combustion engines should be utilized in handling the similar problem in gearing the flywheel to the hob.

Other points of accuracy are treated briefly, and the author concludes his article with a mention of the more successful gear-production practices.

(*Continued on next left-hand page*)

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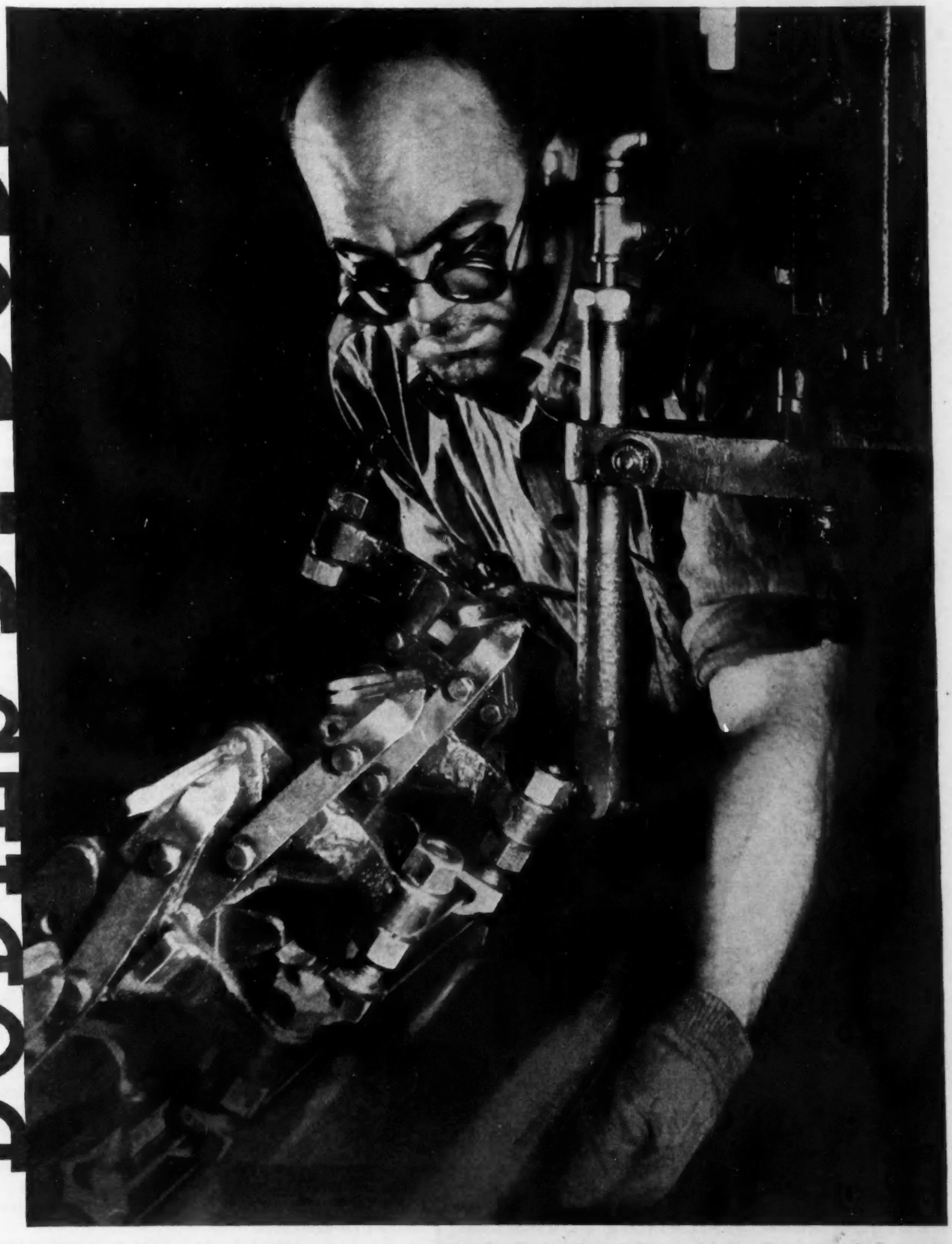

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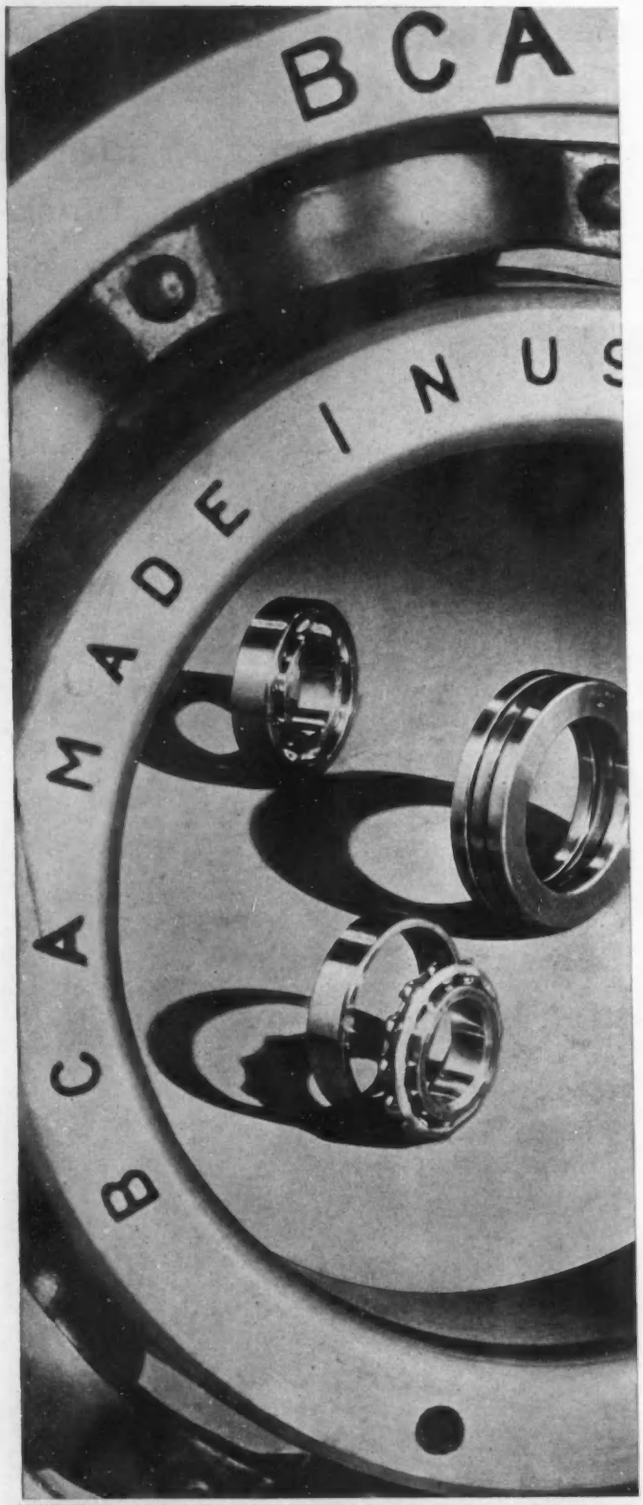

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Notes and Reviews

Continued

ENGINES

The Automotive Ignition Coil. By T. H. Darnell. Report No. 374. Published by the National Advisory Committee for Aeronautics, City of Washington, 1931; 28 pp., 29 figs. [E-1]

This paper, which was submitted by the Bureau of Standards for publication, gives the results of an extensive series of measurements on the secondary voltage induced in an ignition coil of typical construction under a variety of operating conditions. These results show that the theoretical predictions hitherto made as to the behavior of this type of apparatus are in satisfactory agreement with the observed facts. The large mass of data obtained is here published for use both by other investigators who may desire to compare them with other theoretical predictions and by automotive engineers who will here find definite experimental results showing the effect of secondary capacity and resistance on the crest voltage produced by ignition apparatus.

The Comparative Performance of Superchargers. By Oscar W. Schey. Report No. 384. Published by the National Advisory Committee for Aeronautics, City of Washington, 1931; 15 pp., with tables and charts. [E-1]

This report presents a comparison of superchargers on the basis both of the power required to compress the air at a definite rate and of the net engine power developed at altitudes from 0 to 40,000 ft. The investigation, which was conducted at the Langley Memorial Aeronautical Laboratory, included geared centrifugal, turbine-driven centrifugal, Roots, and vane-type superchargers. The report includes a brief discussion of the mechanical limitations of each supercharger and explains how the method of control affects the power requirements.

The results of this investigation show that, for critical altitudes below 20,000 ft., a maximum difference of about 6 per cent exists between the amounts of net engine power developed by superchargers of the various types, when ideal methods of control are employed, but for critical altitudes above 20,000 ft. an engine develops considerably more power when equipped with a turbo-centrifugal supercharger than with any other type. The Roots type gives the lowest net engine power of all at high critical altitudes, because it has the least efficient type of compression.

The throttling method of control used on the geared centrifugal type is very satisfactory at low altitudes from a net engine-power standpoint when compared with the method used on the Roots or turbo-centrifugal types.

Development of an Impinging-Jet Fuel-Injection Valve Nozzle. By J. A. Spanogle and G. T. Hemmeter. Technical Note No. 372. Published by the National Advisory Committee for Aeronautics, City of Washington, April, 1931; 9 pp., 9 figs. [E-1]

During an investigation to determine the possibilities and limitations of a two-stroke-cycle engine having fuel injection and spark ignition, it was necessary to develop a fuel-injection valve nozzle to produce a disk-shaped well-dispersed spray. Preliminary tests showed that two smooth jets impinging upon each other at an angle of 74 deg. gave a spray having the desired characteristics. Nozzles were built on this basis and, when used in fuel-injection valves, produced a spray that fulfilled the original requirements. The spray is so well dispersed that it can be carried along with an airstream of comparatively low velocity or entrained with the fuel jet from a round orifice. This characteristic of the spray from an impinging-jet nozzle limits its application to situations where wide dispersion is required by the conditions in the engine cylinder and combustion-chamber.

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Notes and Reviews

Continued

Investigation of the Discharge Rate of a Fuel-Injection System. By Harold C. Gerrish and Fred Voss. Technical Note No. 373. Published by the National Advisory Committee for Aeronautics, City of Washington, April, 1931; 11 pp., 6 figs. **[E-1]**

In connection with the development of a method for analyzing indicator cards taken from high-speed compression-ignition engines, this investigation was undertaken to determine the average quantity of fuel discharged during each crank degree of the injection period. The fuel discharged by a cam-operated pump and an automatic injection valve was collected in a rotating receiver. The weight of fuel discharged per unit time was determined for various crank-angle positions over the entire injection period.

The results show that 98 per cent of the fuel was discharged during an interval of 25 deg., whereas the duration of the period from the start to the stop of the fuel spray was 68 deg. The duration of the period as obtained in these tests checks with the results obtained with the oscilloscope. During the 29 deg. of crank rotation after the start of injection and the 14 deg. before the stop of injection, only 2 per cent of the total weight of fuel is discharged.

The rate of fuel injection continued to increase for 7 deg. after the pump by-pass valve opened. Calculations show that this interval is required for the pressure wave in the fuel to travel from the by-pass valve to the injection nozzle.

Induction Conditions, Distribution and Turbulence in Petrol-Engines. By S. J. Davies. Published in *Engineering*, Jan. 9, 1931, p. 57. **[E-1]**

The initial investigation herein reported was undertaken to determine the connection between inlet velocity and turbulence. The author makes clear that turbulence may come from two sources. Sufficient kinetic energy may be imparted to the incoming charge in its passage through the inlet ports—that is, during the suction stroke in four-stroke engines—that the effects of the velocities so set up may persist right through the compression period. Turbulence set up in this way, which the author suggests might be called "port" turbulence, depends upon the shape, area and position of the inlet ports and valves, the interval of the induction period and the form of the cylinder. The second type, which may be called "piston" turbulence, is set up, mainly during the compression stroke, by a combination of the form of the piston crown and that of the combustion space in the cylinder-head. In overhead-valve engines the form of the combustion-chamber is especially unfavorable to "piston" turbulence.

After consideration, sets of valves were made having shrouds of two distinct types, single-slot and multi-slot, the valves having the common characteristic that, by means of the shrouds provided, they permit of a reduction of the effective port area of a valve to any desired extent. In the single-slot type, it was possible in addition, by suitably locating the direction of the slot in the shroud with relation to the cylinder, to control the direction of the inflowing charge. The slots in the multi-slot valves, on the other hand, were arranged symmetrically so that the general direction of the charge was roughly the same as that of the normal valves of the engine. With the method adopted for controlling the turbulence, the timing and the complete valve-opening diagram remained constant throughout all the tests.

After a preliminary examination of the test data, it seemed very desirable, since complete and reliable figures for air consumption were available, to consider in each test the efficiencies with which both fuel and air were utilized and to express the results with reference to mixture strength as a basis. It was further desired to compare the

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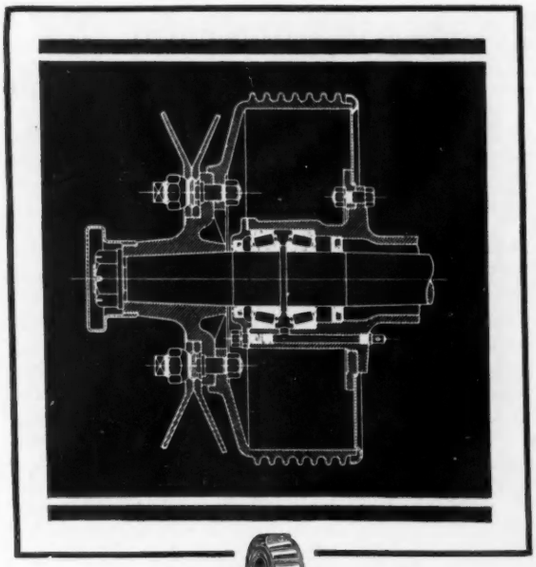

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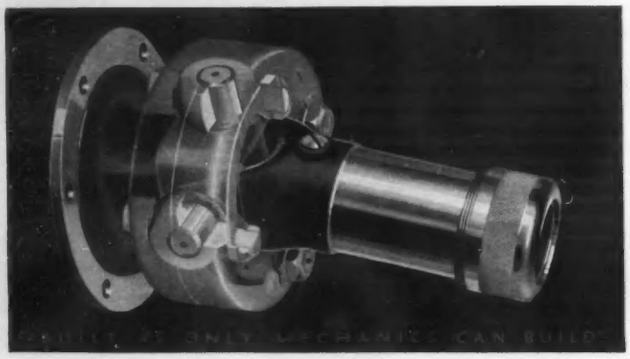

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Notes and Reviews

Continued

performances of the engine with that of a suitable ideal engine, again over the possible range of mixture strength.

The article is concluded in the Jan. 16, 1931, issue of *Engineering*.

United States Army Air Corps Switches from Gear to Vane Type of Fuel-Pump. By F. W. Heckert. Published in *Automotive Industries*, March 28, 1931, p. 512. **[E-1]**

In this article the author outlines the history of the development of fuel systems for aircraft used in the Government service. He describes briefly the performance characteristics of gravity fuel feed, air-pressure fuel feed, wind-driven fuel pumps, Sylphon pumps, electrically-driven centrifugal pumps, gear-type pumps and the C-5 standard fuel-pump of the Army and Navy Air Services. He also gives a complete description and the results of tests conducted recently on the vane-type Romec pump.

In conclusion, the author states that a rotary-type pump along the lines of the Romec is desirable for aircraft engines and is preferred by the Army Air Corps because of its small size, simplicity, reliability, ease of installation, all-round pumping efficiency, durability and the small amount of power required to drive it.

The pump, which is produced by the Martell Packings Co., of Elyria, Ohio, is now in use in Army Air Corps and Navy service airplanes.

Less Diesel and More Power—A Study in High Specific Capacity. Published in *Diesel Power*, February, 1931, p. 66. **[E-1]**

The apparent lack of a rational general basis of Diesel-engine design is emphasized in this article by a logarithmic chart visualizing the relation between cylinder diameter, stroke-bore ratio, and weight per cubic foot displacement, on the one hand, and mean piston speed, mean pressure, and weight per brake horsepower, on the other hand.

The author contends that the efforts of Diesel-engine designers and manufacturers do not seem to have been logically coordinated in rigorously avoiding those practices which unnecessarily increase the weight and bulk of Diesel engines.

In the concluding installment of the article, which appears in the March issue of *Diesel Power*, an attempt is made to shed light on valve and combustion-space design practices which are likely to account for the discrepancies in specific capacity.

Increased Compression-Ratio May Solve Cold-Starting Problems of Compression-Ignition Engines. By Robertson Matthews. Published in *Automotive Industries*, March 28, 1931, p. 508. **[E-1]**

Regulation of the timing of compression-ignition has received about the same amount of attention as did the control of detonation 20 years ago, asserts the author. Compression ignition involves a different set of considerations from spark ignition, and among these that of the timing of fuel injection is but a part. The author proceeds with a consideration of the factors involved in starting a compression-ignition engine.

Three desirable conditions for starting a cool engine are set up: (*a*) a minimum of either directed or other turbulence, (*b*) fuel atomization of almost excessive fineness, and (*c*) means for compensating for the effect of piston leakage on final compression pressure, and hence on final compression temperature.

After pointing out the advantages of increased compression, Mr. Matthews describes briefly certain attempts that have been made to limit this higher ratio to starting and light-load conditions and to provide for its reduction during normal running. One such provision is the auxiliary chamber of variable capacity by means of which the clearance volume, that is, the combustion-chamber capacity, can be

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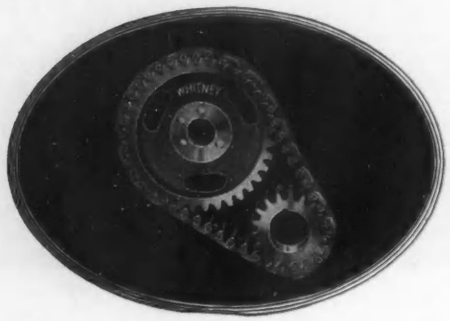

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Notes and Reviews

Continued

altered at will and hence the volumetric compression-ratio varied. The author treats of the possibilities of this design and suggests that logical forward steps would seem to include its consideration as a "pep chamber" for aeronautic engines at altitude, the additional weight being in part offset by the less weight necessary because of better control of maximum pressures.

Injection, Ignition and Combustion in High-Speed Heavy-Oil Engines. By S. J. Davies and E. Giffen. Paper presented before a joint meeting of the Institution of Automobile Engineers and ten other engineering societies, London, England, March 31, 1931. [E-1]

The authors sketch briefly the history of efforts to develop a compression-ignition engine of the airless-injection type. They point out that engines which are the lineal descendants of these early engines, namely those in which the fuel is injected directly into a combustion-chamber of simple form and known conveniently as the direct-injection type, constitute an important proportion of the engines that are working successfully at high speeds. The second main type of high-speed heavy-oil engine, the ante-chamber type, is a parallel development. The third main type, that employing an auxiliary air-chamber, although by virtue of the divided combustion-chamber apparently related to the ante-chamber type, may be more properly regarded as a special solution of the problems of the direct-injection type.

In stating the problems met with in high-speed heavy-oil engines, the reasons why successful airless injection was brought about slowly are enumerated. Assuming that, as is the case in its application to transport, the engine must be flexible both as regards speed and load, these problems are: (*a*) metering of the fuel to the engine in correct quantities at all desired speeds and loads; (*b*) delivery of the fuel into the cylinder under these conditions at a suitable pressure and at such a rate that combustion may proceed so that, on the one hand, it is complete at a point in the expansion stroke sufficiently early to assure good thermal efficiency, and, on the other hand, that, the rise of pressure behind the piston is neither irregular nor too sudden, conditions which would cause "roughness" in running; (*c*) suitable subdivision or atomization of the fuel and suitable control of its direction and penetration, and (*d*) control of the motion of the air in the cylinder so that the mixing of fuel and air will lead also to satisfactory rates of combustion.

The paper deals with the present state of knowledge on these problems under two headings: processes in the fuel-injection system, and processes within the cylinder.

In conclusion, the authors suggest that fuller knowledge is urgently needed on the following points:

(1) Ignition lag, and how this is influenced (*a*) by rate of fuel injection, that is, by the fuel-pumps, nozzles and systems; (*b*) by regulated movement of the air; (*c*) by cylinder design, and (*d*) by various fuels.

(2) Fuels and their physical characteristics; namely, data of a nature similar to those concerning gasoline-engine fuels made available by the work of Ricardo, Tizard, Pye and others.

The authors urge the cooperative action of technical institutions on these problems.

Les Nouveau Modèles de Moteurs Diesel Légers pour l'Aviation. By G. Delanghe. Published in *Le Génie Civil*, March 28, p. 309, and April 4, 1931, p. 337. [E-1]

The Clerget engine, developed by its designer with the support of the French aeronautical technical services, receives the principal emphasis in this review of recent developments in light-weight high-speed Diesel engines for aircraft.

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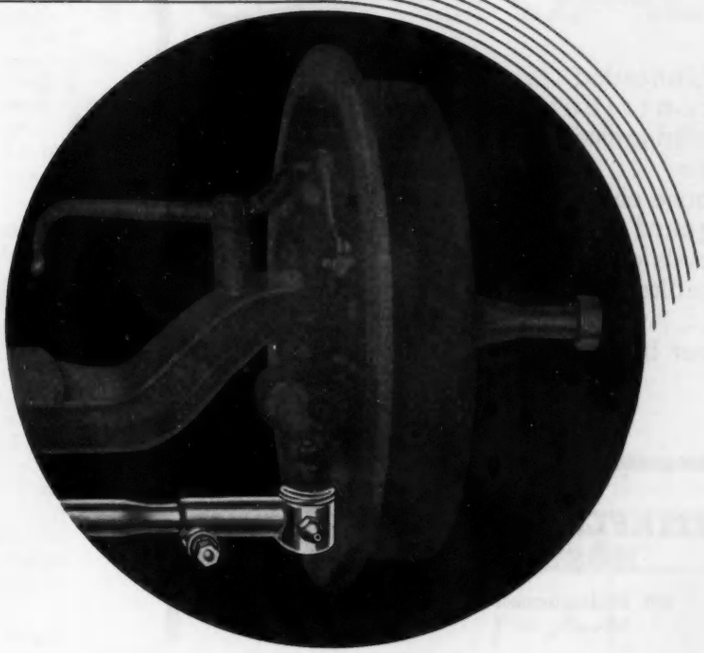
EASY STEERING



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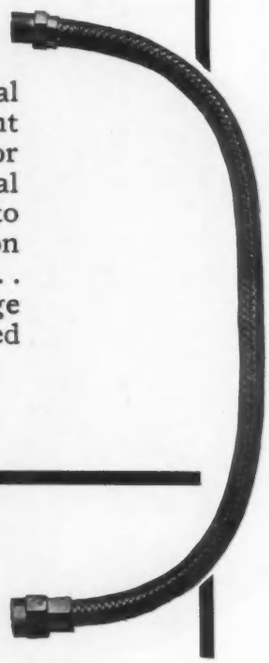

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Notes and Reviews

Continued

The design of the engine is based on Clerget's leaning toward the four-stroke cycle as being better adapted to altitude operation than the two-stroke cycle and on his belief in systematic supercharging beginning at ground level instead of at some particular height. In this engine, it is claimed, an excessive air charge is not necessary to obtain complete combustion, as is the case in many other injection engines. Special shaping of the combustion-chamber for augmenting turbulence is also dispensed with. The fuel-feeding system is characterized as one of the original features of the design.

Other developments described are the Beardmore, Ricardo, M.A.N., Burmeister and Wain, Fiat, Garuffa and the Sunbeam-Coatalen.

Zweimetall-Kolben. By Dipl.-Ing. Mahle. Published in *Automobiltechnische Zeitschrift*, March 31, 1931, p. 205. **[E-1]**

Under the designation of bi-metal pistons, the author includes only those in which the head is of one material, usually aluminum alloy, and the stem of another, usually cast iron or steel. He sets forth the reasons that gave rise to such constructions and describes about 20 different pistons of this type.

Why have these pistons not gained a foothold in the automotive industry in any country? the author asks. He finds his answer in an analysis of the present aluminum piston, which he asserts has overcome the defects of the early light-alloy piston. These defects, unduly high thermal expansion and low wear resistance, having been obviated, the reason for the bi-metal piston no longer exists.

Diesel Engine Lubrication; the Influence of Construction on Choice of Lubricants and Bearing and Air-Compressor Requirements. Published in *Lubrication*, January and February, 1931. **[E-4]**

The Texas Co. has devoted the January and February issues of its monthly bulletin, *Lubrication*, to an analysis of lubrication problems in Diesel engines. The first of the two articles discusses the characteristics of Diesel engines and their lubricating systems. The concluding article covers mechanical force-feed systems, pressure-circulation systems, splash oiling, ring and chain oilers, character of the burdens put upon the oil, and the effect of temperature, moisture and other outside influences.

MATERIAL

A Study of Welded Metals under Fatigue Tests. By G. E. Thornton. Engineering Experiment Station Bulletin No. 34. Published by the State College of Washington, Pullman, Wash., 1930; 31 pp., illustrated. **[G-1]**

The object of the tests undertaken in the study herein reported was to compare the different types of welds in which a flexure of the specimen occurs when subjected to a continuous series of stress reversals. Such a condition is present in a member under continuous or spasmodic vibration. The tests were undertaken by the Engineering Experiment Station of the State College of Washington in cooperation with the mechanical engineering department of the same institution and with the American Welding Society.

The field covered in this work consists of tests of oxy-acetylene welds, resistance welds and flash welds, and some work on atomic hydrogen and metallic arc-welds.

In determining a policy of securing specimens, it was decided to test small specimens in fatigue and to obtain a true cross-section of the welding field by soliciting welded coupons from companies doing different types of welding. The average of these tests gives a lower result than would be obtained if one experienced man were doing all the

(*Continued on next left-hand page*)

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Heavy Die Forgings

THE PARK DROP FORGE COMPANY
Cleveland, Ohio

Notes and Reviews

Continued

welding with the knowledge that his welds were to be tested for data. The author believes that this cross-section of the entire field is a much better indication of what to expect from welds than the best results obtained by any one individual.

The author indicates that the study will be continued with tests on the different types of shielded metallic arc-welds and on specimens of all types of welds which have been uniformly heat-treated.

Fatigue Strength of Carbon and Alloy-Steel Plates as Used for Laminated Springs. By R. G. C. Batson and J. Bradley. Published in *Engineering*, Mar. 20, 1931, p. 405. [G-1]

Tests conducted at the National Physical Laboratory in England in 1925 and 1926 on complete laminated springs showed that the limiting ranges of stress obtained were only from 22 to 40 per cent of the ranges which the materials would stand in the form of turned and polished specimens, and appeared to indicate the existence of a source of weakness in the outer skin of the plates of which the springs were composed.

The tests described in this paper were started in 1926 and were undertaken in order to discover whether a substantial improvement could be made in spring plates by grinding or polishing them to remove the outer skin. Later, when such an improvement was found, the tests were extended to obtain information on the effect of heat-treatment on the fatigue strength when the plates were heat-treated either before or after machining the surface.

The results showed that the conditions of the surface layer of spring-steel plates was the principal factor in causing the fatigue resistance of complete laminated springs to be considerably below that which would be expected from the known mechanical properties of the material of which they are composed. This suggests a probable explanation of the fractures of laminated springs in practice, in the very low limiting ranges of stress obtained from unmachined plates compared with those given by machined specimens upon which, no doubt, the data of design have hitherto been based.

Thickness of the deleterious layer was found to be small. It was almost completely removed by machining 1/16 in. from the surface, and in most cases it was probable that removal of a much thinner layer would suffice. The "surface effect" was found to be produced by hardening and tempering. Only slight improvement was obtained by heat-treating the spring plates after a thin layer had been machined from the surface of the rolled material.

An Investigation of Steels for Aircraft-Engine Valve Springs. By A. Swan, H. Sutton and W. D. Douglas. Published in *Engineering*, Feb. 27, 1931, p. 314. [G-1]

The not infrequent failure of valve springs in service gave the impetus to the research work reported in this article, which appeared in two parts, the second part in the March 13 issue of *Engineering*.

It was recognized that valve springs must be used in positions of small compass, and in consequence of this and the large number of repetitions of stress they have to withstand, the duty they perform is arduous and necessitates the use of the best-quality materials. The fractures noted were usually typical of those resulting from fatigue, and occurred in most cases at a point about one coil distant from the end of the spring.

Surging of the springs was known to occur, and some experimental work was done at the Royal Aircraft Establishment in England to determine to what extent this might account for the failures. An apparatus was designed by Mr. Savage, of the Royal Aircraft Establishment, in which one or more springs operated by a cam could be

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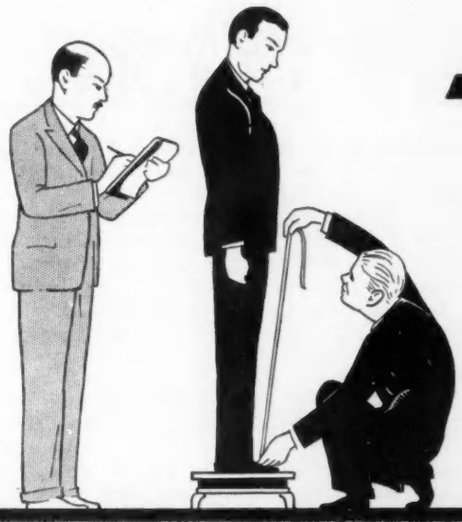

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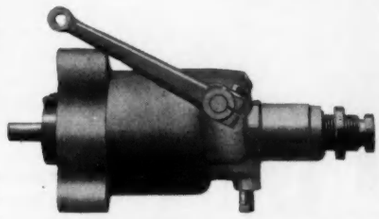

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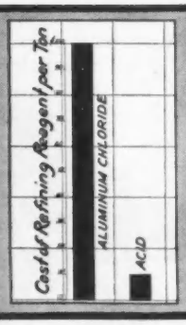

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Notes and Reviews

Continued

studied stroboscopically, and the exact coil movements and positions during the rise and fall of the cam recorded to a magnified scale.

The authors discuss the broad general conclusions drawn from this work. The fact was clearly shown, they declare, that the surging effect reached a maximum at certain well-defined camshaft speeds, these speeds being easily calculable and dependent on the dimensions of the springs, and, furthermore, that the maximum stress produced and the range of stress undergone might be considerably increased by the surges.

As a preliminary to the contemplated research on valve springs and spring wires, a summary of the particulars of many service springs was made. Very diverse materials are used, ranging from cold-worked carbon steels to heat-treated alloy steels, and the stresses also have a wide variation.

The Use of Elektron Metal in Airplane Construction. By E. I. de Ridder. Translated from Jahrbuch 1929 der Wissenschaftlichen Gesellschaft für Luftfahrt. Technical Memorandum No. 608. Published by the National Advisory Committee for Aeronautics, City of Washington, February, 1931; 22 pp., 46 figs. [G-1]

The tendency in aircraft construction is toward higher performance and greater economy. From the aerodynamic standpoint this means minimum possible drag by streamlining, and, from the structural viewpoint, saving in weight by using light metal.

Elektron is a magnesium-base alloy and the lightest of the light metals, and, as such, merits special attention because it meets the demand for lighter construction. The report deals briefly with those characteristics of Elektron which are of interest to the constructor who uses it.

Seewasserbeständigkeit Galvanischer Überzüge auf Eisen und Leichtmetallen. By Erich K. O. Schmidt. Published in *Zeitschrift für Flugtechnik und Motorluftschiffahrt*, March 14, 1931, p. 141. [G-1]

Tests are here described which were designed to throw light on the value of various types of coating for the protection of aircraft parts from salt-water corrosion. Both metallic and non-metallic coatings applied by the galvanic process to ferrous metals and light alloys were included in the investigation, but the main emphasis is placed on cadmium.

In the foreword, the methods of producing cadmium and its physical characteristics are described. The high specific gravity of cadmium is stated to detract from its value for aircraft purposes, particularly where light alloys are the base, since the lighter pure-aluminum plating has proved so successful. However, cadmium may be used to advantage where the structure is made up of ferrous metals and aluminum in combination, since cadmium is suitable for both types of base metal.

The tests extended over the period from June, 1929, to the autumn of 1930, and the following conclusions are drawn from them: For ferrous metals, lead dioxide is unsuitable, chromium cannot be used, zinc is not sufficently durable, cadmium plus tin is not so good as cadmium alone, and cadmium always furnishes good corrosion protection. In the light-alloy tests, cadmium did not protect Elektron AZ 551, rubber furnished only slight protection for duralumin and Lautal, and cadmium was found to be a good corrosion-resisting coating for duralumin and Lautal.

MISCELLANEOUS

The Transference of Heat from a Hot Plate to an Air Stream. By Franz Éliás. Translated from *Abhandlungen aus dem Aerodynamischen Institut an der Technischen Hochschule Aachen*, No. 9, 1930. Technical Memorandum No. 614.

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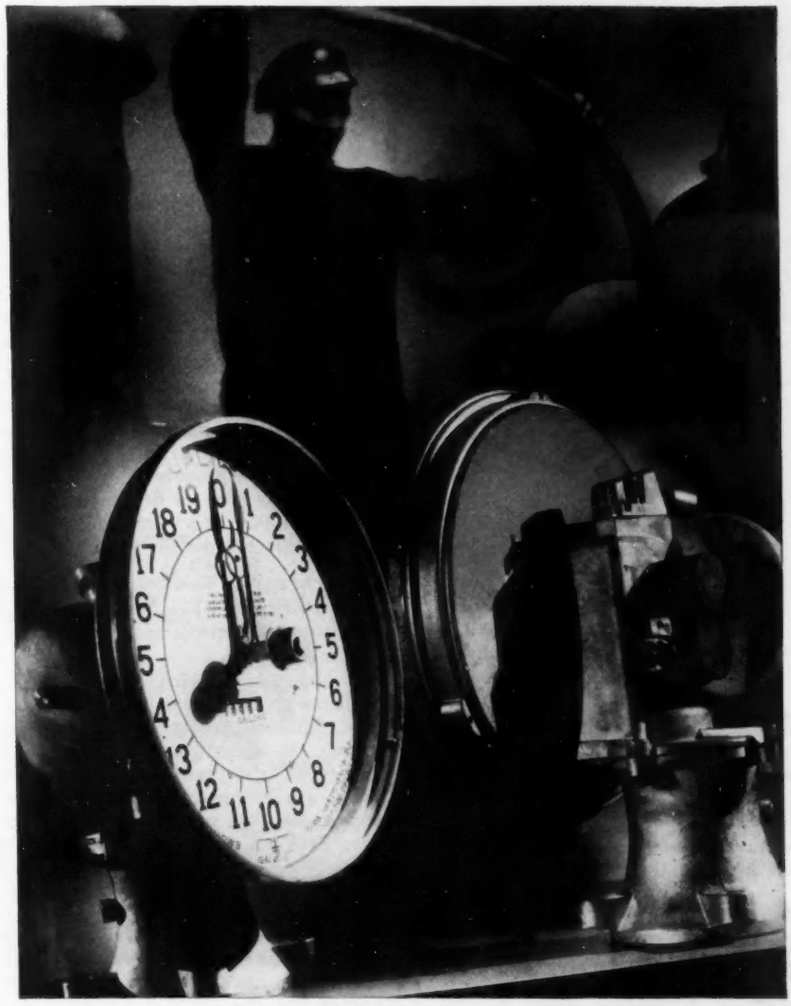

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Notes and Reviews

Continued

Published by the National Advisory Committee for Aeronautics, City of Washington, April, 1931; 25 pp., 55 figs. **[H-1]**

Neuzeitlicher Verkehrsbau. Edited by H. Gescheit and K. Wittmann. Published by Müller & I. Kiepenheuer, Potsdam, Germany; 334 pp.; 389 figs. **[H-1]**

Ease of access to available transportation means determined the location of the cities of yesterday; suitability to the increasingly prevalent and speedy transportation of today must determine the form and construction of the city of the future. This is the thesis of the editors of this volume, in which is collected a large number of plans, photographs and descriptions of buildings and ground layouts for the housing and starting points of transportation means operating on water, land and in the air.

One of the suggestions advanced is that the ground level of the future settlement be consecrated to the use of pedestrians alone. Vehicular approach to and transportation through the city shall be through underground tunnels, with underground or skyscraper storage space for automobiles and aircraft. Garage plans of a large variety of forms are presented, as well as boat landings and airports. The book is designed to jar the reader from a conventional rut of thought on transportation buildings and city architecture into a vein of progressive speculation.

Betrachtungen über die Internationale Automobil-Ausstellung Berlin 1931. By Robert Conrad. Published in *Automobiltechnische Zeitschrift*, Feb. 25, 1931, p. 115. **[H-1]**

To be able to think from the customer's viewpoint, to be sufficiently conservative to preserve custom-honored forms and yet sufficiently progressive to incorporate in these forms the improvements made possible by science and enforced by competition—these are the qualifications necessary in a successful automobile manufacturer. The author expresses this opinion in the course of a review of the international automobile show held in Berlin in 1931.

Taking up the separate classes of automobile, he writes first of the high-priced luxury vehicle, which he terms the quality pacemaker for the regular production job. He believes it unnecessary to rigidly define other classes of car, such as the medium-weight or light car, and emphasizes the importance of considering not only the size of the engine but the ratio of power to weight.

Of front-wheel drive vehicles, the Cord was the only representative in the large passenger-car class. The NAG front-wheel-drive car, concerning which much has been written, was not ready for exhibition. Two small cars, the Stoewer and the DKW, and two trucks, the Vomag and the Rumpler, also had this type of construction. Warnings are sounded against the too unquestioning acceptance of front-wheel drive or of independent wheel-suspension, the latter of which has so far not been incorporated in any of the large or well-known medium-size passenger-cars.

Further topics discussed are price, commercial vehicles and improvements in transmissions.

Standardization. By L. A. Legros. Paper delivered before the Institute of Automobile Engineers in London, March, 1931. **[H-3]**

Standardization has a varied and interesting history. Typefounding was the first trade that required the production of large numbers of pieces of metal mating together interchangeably. More than 100 years later, Whitworth proposed a system of standards for screw-threads. But the advantages of standardization were not seriously considered by some trades and the public until the advent of the railroad.

Establishment of the National Physical Laboratory in England in 1897 provided the impartial and fully qualified body equipped with standards and appliances for the check-

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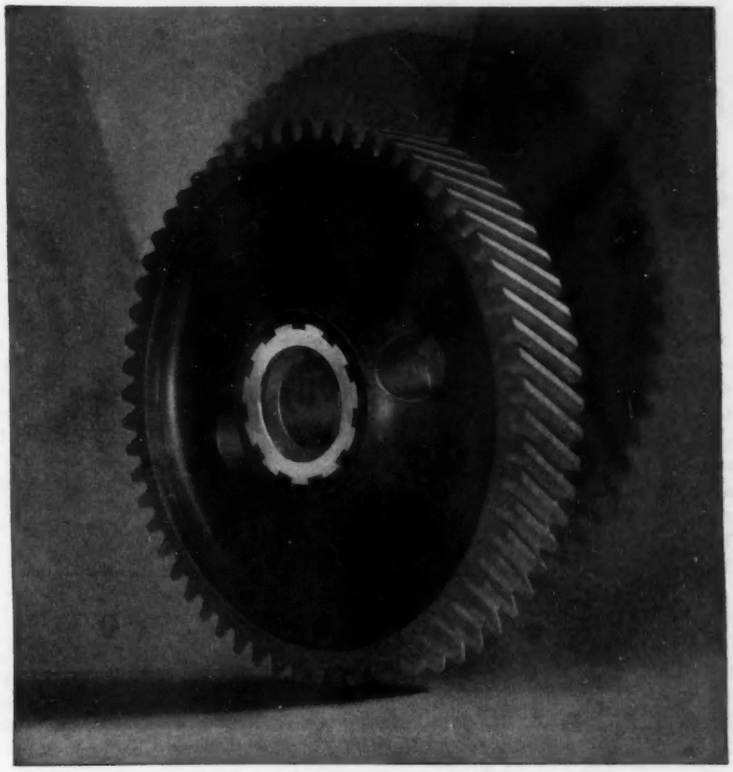

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Notes and Reviews

Concluded

ing and working of standard gages. Following this, several engineers and institutions carried on research in the various trades. Consequently, two systems of limits, arose, with different measurements for tolerance and allowance.

Many critics fear that standardization may interfere with invention and progress. They forget that many standards are provisional and subject to periodic review and revision. The famous automobile manufacturer says, "There is a standardization which marks inertia and a standardization which marks progress."

The author feels that a vast field for standardization exists in the automobile industry. Certain standards for such things as wheels, springs and tires could be interchangeable with Continental standards and should be made available to the owner. Then there are matters of design to suit the driver by standardization of positions of shift lever for the various speeds and of brake lever for its on and off position, as well as a standard arrangement of clutch, brake and accelerator pedals, and also of the self-starter and lamp switches, giving uniformity of driving as far as it is practicable.

TRACTOR

Nebraska Tractor Tests, 1920-1930. Bulletin 255. Published by the University of Nebraska, College of Agriculture Experiment Station, Lincoln, Neb.; March, 1931; 28 pp., and chart. [M-1]

With the close of the testing season of 1930 came the end of the 11th year of tractor testing at the University of Nebraska. The number of complete tests conducted and reported each year was as follows: 1920, 65; 1921, 15; 1922, 5; 1923, 12; 1924, 10; 1925, 8; 1926, 12; 1927, 16; 1928, 7; 1929, 16; 1930, 10—a total of 176.

This bulletin summarizes the results of 64 of these tests and includes data on all tractors reported by their manufacturers as on the market Jan. 1, 1931. If a tractor has been tested but is not listed in this bulletin, the reader may safely assume that its manufacture has been discontinued.

All tractors tested are certified by their manufacturers as being stock-model machines conforming to specifications filed with the application for test. No special or high-test fuels are used. All results shown in reports are those actually attained in tests and are without corrections or allowances for friction, temperature, altitude and so forth. These results are accomplished with the tractor in charge of skilled operators employed by the University.

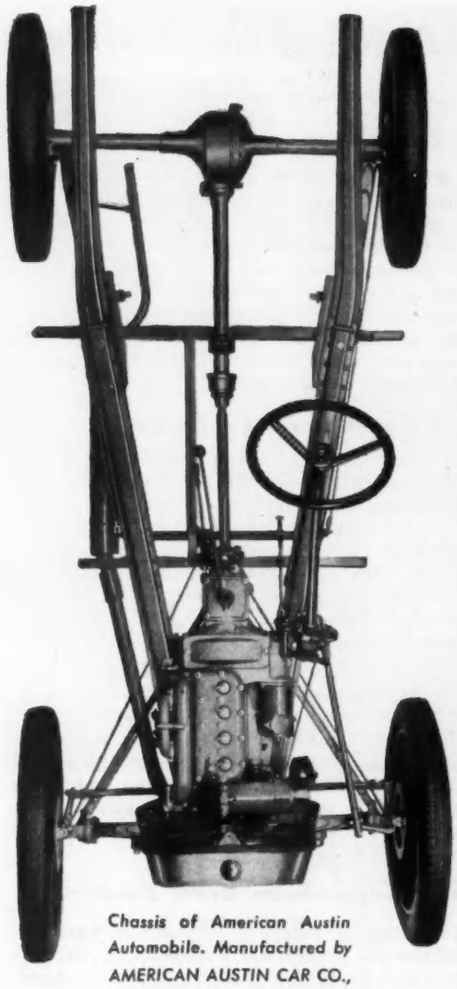
In 1928 the "one carbureter setting" was adopted, and all results shown on reports since that time were attained with the carbureter adjustment remaining unchanged throughout the complete test.

A summary of the results reported in the bulletin is given in chart form.

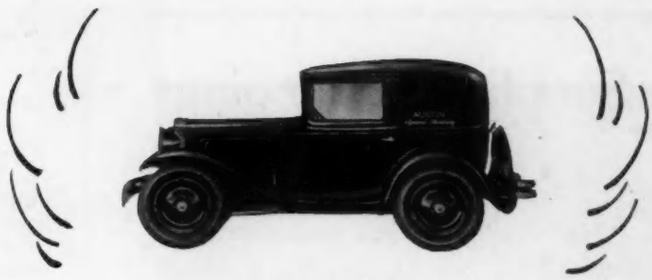
Le Xe Salon de la Machine Agricole. By G. Coupan. Published in *Le Génie Civil*, March 7 p. 232; March 14, p. 263; and March 21, 1931, p. 293. [M-1]

Despite the economic depression, the tenth annual exhibition of agricultural machinery, in which are assembled products of all nations destined for world-wide use, attracted as many visitors as in previous years and satisfactorily stimulated the business of the exhibitors. The 750 stands occupied about 500,000 sq. ft. and accommodated the wares of 700 manufacturers and dealers. An interesting innovation this year was a section devoted to new machines.

Among agricultural machinery, the tractor is said to be king. Increased power for large-scale cultivation, the substitution of tracks for wheels, and the adaptation of engines to heavy fuels are some of the tendencies noted. The failure of the gas producer to make headway in this field is noted, as well as the development of small tractors for garden work. The newer and more interesting exhibits are described in detail.



Chassis of American Austin Automobile. Manufactured by AMERICAN AUSTIN CAR CO., INC., Butler, Pennsylvania.



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King pin
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GMC No. 3145 Steel
Crankshaft
Clutch plate hub

SAE No. 3115 Steel
Front shackle bolts

SAE No. 3140 Steel
Inlet valves

SAE No. 2330 Steel
Front and rear spring clips
Brake cams and
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SAE No. 3135 Steel
Connecting rod cap and bolt

SAE No. 3240 Steel
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THE American Austin is an outstanding example of the light weight, short wheel-base type of automobile first popularized abroad and now advocated in America as a result of traffic congestion and the premium placed on parking space. Mechanically the American-built Austin is patterned after the British Austin which has won 500 prizes for speed, power, economy and general performance.

To achieve rugged stamina and at the same time keep size and weight to a minimum, Austin engineers specify tough, dependable Nickel Alloy Steels in accordance with the best automotive practice. The impressive list of Nickel Alloy Steel parts in the Austin indicates the high quality that has been built into this sturdy, light-weight car.

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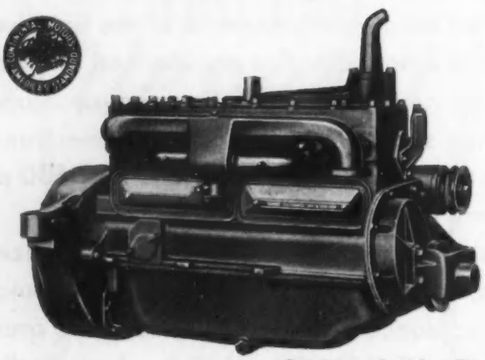

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Personal Notes of the Members

(*Continued from p. 698*)

Co., of Pontiac, Mich., with which he held various positions until he joined the Tank Corps of the Army in 1918. Following the close of the war, he returned to the truck company as assistant branch manager in Chicago. In 1926 he became district representative of the Yellow Truck & Coach Mfg. Co. in North and South Carolina.

Mr. Gossard was admitted to Member Grade in the Society in May, 1929, and last year was appointed a member of the Transportation and Maintenance Committee, of which he is also a member this year.

R. E. Wilson Becomes a Director

To complete reorganization of the Standard Oil Co. of Indiana under the modernized corporation act of the State of Indiana, Louis L. Stephens, general counsel, and Robert E. Wilson, head of the development and patent department of the company, were elected members of the board of directors on May 11. No fundamental change in the corporate structure of the company is involved in the reorganization but the number of directors has been increased from 11 to 13. The annual meeting on May 7 authorized the board of directors to choose two additional directors.

Mr. Wilson, who has been a Member of the Society since 1921, is assistant to the vice-president in charge of manufacturing of the Standard Oil Co. of Indiana. He is a member of the Research Committee of the Society and of the Lubricants Division of the Standards Committee and is the author, individually and in collaboration with others, of a number of papers on fuels and lubricants presented at meetings in recent years.

Officers of Guggenheim Medal Fund

At the annual meeting on May 6 of the Medal Fund organized to administer the gold medal, founded in 1927 by the Daniel Guggenheim Fund for the Promotion of Aeronautics, for notable achievement in aeronautics, the following officers were elected: President and chairman of the board, Admiral H. I. Cone, of the United States Shipping Board, representing the American Society of Mechanical Engineers; vice-president, Edward P. Warner, editor of *Aviation*, representing the Society of Automotive Engineers; secretary and treasurer, Alfred D. Flinn, director of the Engineering Foundation. Admiral Cone, Mr. Warner and Major E. E. Aldrin, aviation manager of the Standard Oil Co. of New Jersey and also a member of the S.A.E., were elected members of the executive committee.

The third Daniel Guggenheim Gold Medal has just been awarded to Dr. Frederick William Lanchester, of Birmingham, England, for contributions to the fundamental theory of aerodynamics. The first award was made to Orville Wright and presented to him in April, 1930, and the second was made to Dr. Ludwig Prandtl and presented to him the following September.

Eight members of the medal corporation are chosen from the S.A.E. and the American Society of Mechanical Engineers. Seven foreign organizations representing as many countries are also represented on the board of award. The S.A.E. members on the board are Major E. E. Aldrin, Capt. E. S. Land, Dr. George W. Lewis, William B. Stout, Admiral H. I. Cone, Arthur Nutt and Edward P. Warner.

Carl O. Barnkow, formerly mechanical engineer in the production department of the A. B. See Elevator Co., of Jersey City, N. J., has accepted a position as layout draftsman with the Seaberg Elevator Co., of Brooklyn, N. Y.

E. L. Beamon has been transferred from his position as supervisor of the motor testing laboratory of the Tide Water Oil Co., of Bayonne, N. J., and is now occupying the position of sales engineer of the Middle Atlantic territory, with headquarters in Philadelphia.

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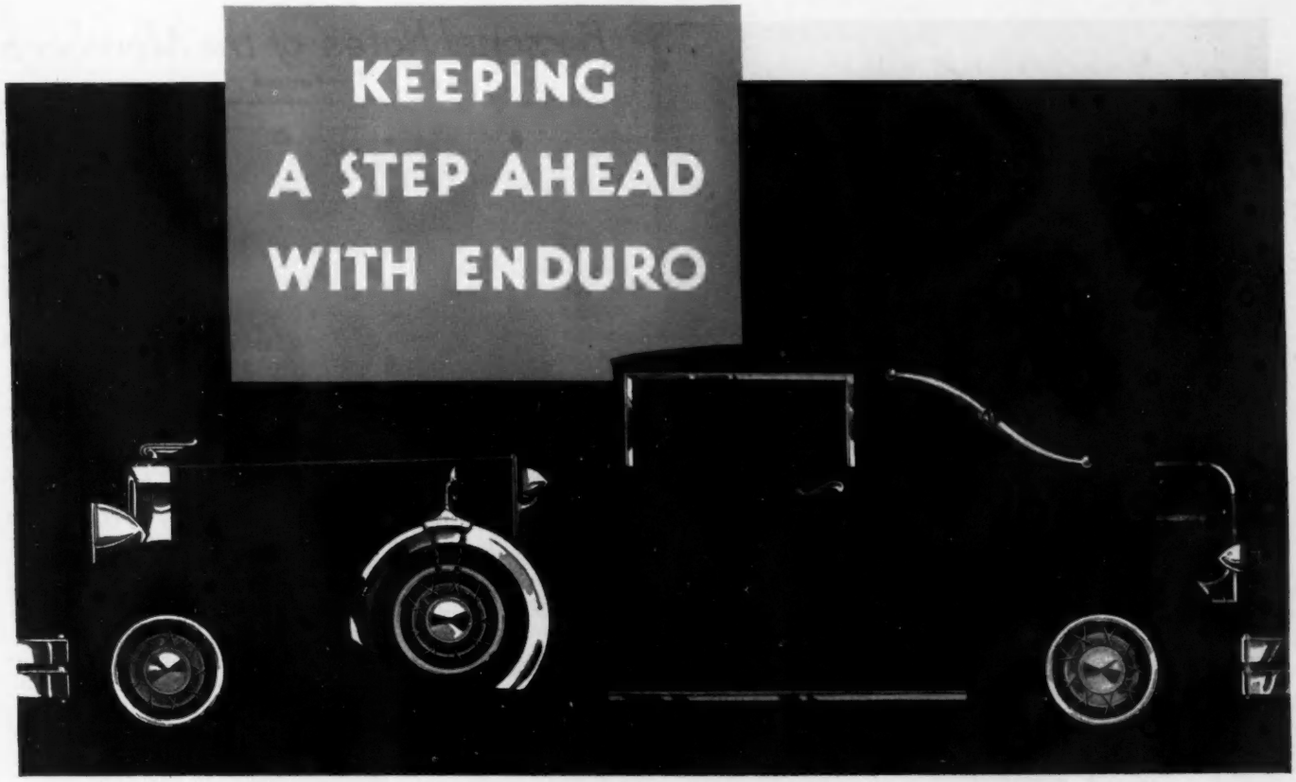

STYLING . . . WITH A TOUCH OF "STAINLESS"

The manufacturer who says "We can't use stainless steel on our car" in a few short months may be saying "We can't get the public to appreciate the hidden values we are giving in our car."

Hidden values there may be, but the things that build popularity and sell cars are the things that the buyer can see, the visible evidence that the maker is abreast of the times, giving not skimping, looking ahead toward tomorrow's demands —not back on past acceptance. Never forget that the motor buying citizen, millions of him, knows what he wants—dependable and economical transportation with beauty and style.

The trend is to Enduro, Republic's Perfected Stainless Steel, for those many motor parts that "style." Because weather has no effect upon it, and because rust, tarnish and corrosion are strangers to this never changing metal, it is particularly suitable for exterior use. Because it is the same all the way through, there is no finish to wear or polish away. And because it marks the car it adorns as keeping a step ahead of less finely appointed cars it lessens sales resistance.

Executives whose vision enables them to look through production costs into the realm of sales, should investigate the possibilities of Enduro.

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MASSILLON, OHIO

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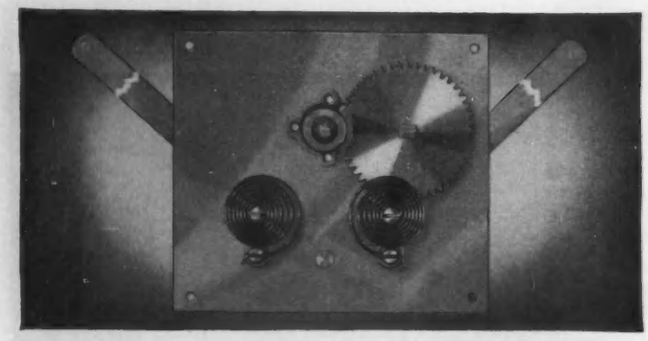
REPUBLIC'S PERFECTED STAINLESS STEEL

Enduro is sold only through Republic Sales Offices and Authorized Distributors.

"Manufactured under license from the Chemical Foundation, Inc., under basic patents No. 1316817 and No. 1339378."



Common Sense Window Regulators Have and Are Made Good

Long the standard for quality in the automotive industry, COMMON-SENSE continues to offer the finest and most complete line of window regulators.

Model No. 6-322 COMMON-SENSE is now the leading type of regulator for the partition and convertible job. Other models equally popular for windows best fitted with double arm regulators.

COMMON-SENSE are selected by leaders in the industry because of their practical originality, skill, the facilites, the experience and the rigid standards of quality have placed them as real leaders in this field.

Send for the COMMON-SENSE Chart showing the mechanical details of the various types.

ACKERMAN-BLAESSER-FEZZEY, INC.

1258 Holden Avenue Detroit, Michigan

Export Distributors—Nolan, McNeil & Co., Inc., 109 Broad Street, New York, N. Y.

Canadian Representatives—Colonial Traders, Ltd., Chatham, Ontario

FELT

The Versatile Product

AMERICAN FELT COMPANY, largest Felt manufacturers in the world, would gladly cooperate with your engineers in solving the most difficult problems. The diversified uses of Felt are really amazing.

Our complete and modern Felt Cutting Plant at Detroit, as well as our five Felt Mills, has provided the Automotive Industry with an entirely dependable source of supply. We are fully equipped to supply Felt in bulk or cut to the most exacting specifications.

American Felt Company

TRADE MARK

General Offices

315—4th Ave., New York

Boston Chicago Philadelphia

Detroit San Francisco St. Louis

Personal Notes of the Members

Continued

Sam L. Boukard has recently assumed the duties of manager of the Fibrecraft products division of Nicoll & Co., of San Francisco. He previously was secretary-treasurer and a director of the American Woodlite Corp., of San Francisco.

C. B. Buxton is now assistant works manager of the McIntosh & Seymour Corp., of Auburn, N. Y., a division of the American Locomotive Co., which is devoted to the manufacture of Diesel engines. He was formerly connected with the works of the last-mentioned company at Schenectady, N. Y.

Having relinquished his position as chief instructor in the motor department of the Technical Institute, in Hamilton, Ont., Canada, **J. L. Cleland** is now shop director at the Collegiate Institute, North Bay, Ont., Canada.

L. A. Corey, who formerly was connected with the General Instrument Co., of LaCrosse, Wis., has left that organization to become secretary and treasurer of the Northern Engraving & Mfg. Co., in the same city, manufacturers of automobile equipment, particularly stampings.

W. W. Cromley, formerly sales engineer with the Buda Co., of Harvey, Ill., is now connected with the Hercules Motors Corp., of Canton, Ohio, in the same capacity.

Frank M. Germane, who was formerly president of the Bearings Co. of America, in Philadelphia, is now a special sales representative for the Budd Wheel Co., of Detroit.

It is announced that **Lewis R. Gwyn, Jr.**, has left the American Railway Express Co.'s motor-vehicle department at Brooklyn, N. Y., of which he had been assistant superintendent, to become designing engineer for the Ward Motor Vehicle Co., of Mount Vernon, N. Y.

Having left the Aero Corp. of California, of Los Angeles, **W. A. Hamilton** now holds the position of superintendent of maintenance in the western division of the Transcontinental & Western Air, Inc., at Glendale, Calif.

J. F. Hunsaker is now a salesman for the Gurley Lord Tire Co., of San Francisco. He previously served as sales transportation engineer and manager for the Fisk Tire Co., of the same city.

Robert J. Kenworth has severed his connection as vice-president of the B. & J. Auto Spring Co., of Brooklyn, N. Y., and is engaged on plans that are expected to be consummated soon.

V. C. Kloepper, having resigned his position as general factory superintendent of the American Metal Products Co., of St. Louis, is now connected with the Elliott Stephens Machinery Co., of the same city, in the capacity of engineer.

John M. Lassells has accepted the position of manager of the engineering department of the South Philadelphia works of the Westinghouse Electric & Mfg. Co., of Philadelphia. This is an advancement from his former position of manager of the mechanics division of the company's research laboratories.

Ivar C. Lindgren has resigned his post as service manager of the Bonney Nash Motors, Inc., of St. Paul, Minn., and is now employed by the Nash Midwest Motors, Inc., of Kansas City, Mo.

Bart Lund, who formerly owned the Byrne Battery Co., in St. Louis, has given up that business and is now in Hammond, Ind.

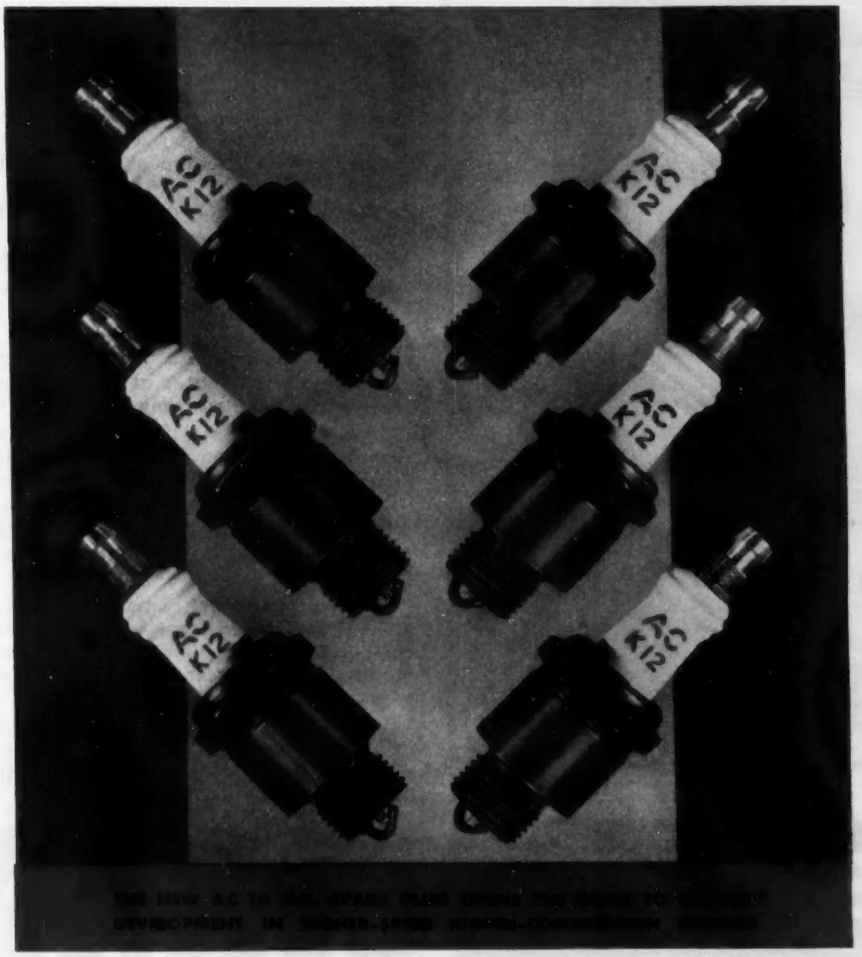
H. C. Marble, formerly vice-president in charge of service of the White Motor Co., of Cleveland, is now vice-president and general manager of the Theatre Garage Co., in the same city.

J. B. Mason has resigned his position as superintendent of the motor-transport division of the Pure Oil Co., Fort Worth, Texas, and has tranferred his Section membership to the Syracuse Section.

J. N. Nead, formerly chief metallurgist with the American Rolling Mill Co., of Middletown, Ohio, now holds a position in the same capacity with the Inland Steel Co., of East Chicago, Ind.

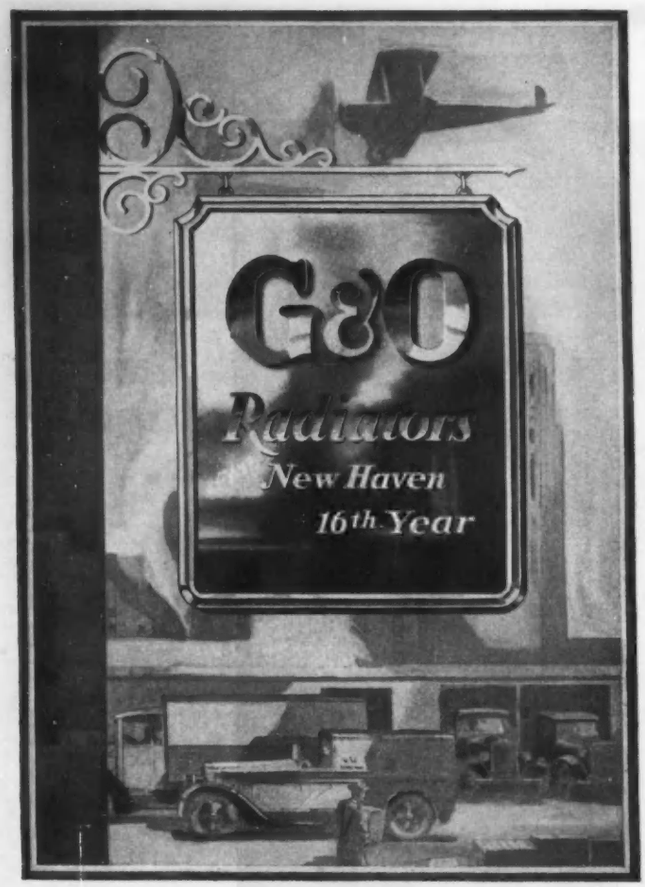
(*Concluded on next left-hand page*)

AC AC
AC AC
AC AC



In step with today's trend in automobile engine design, AC engineers have perfected a smaller spark plug—incorporating all of AC's quality features—introducing a degree of performance never before attained. The new 14 mm. AC spark plug insures greater freedom from fouling. Its life is longer. Less space is required for its location in the cylinder. And this new AC contribution has a wider heat range than any spark plug previously developed—which means full spark plug efficiency and smoother engine performance over a wide range of operating conditions.

AC SPARK PLUG COMPANY, FLINT, MICHIGAN



Personal Notes of the Members

Concluded

Announcement has been received that **Otis Presbrey**, formerly president of the Otis Engine Corp., of Brooklyn, N. Y., is now acting as sales engineer for the Lidgerwood Mfg. Co., at Elizabeth, N. J.

Fred Rath, formerly tool engineer with the Oakland Motor Car Co., of Pontiac, Mich., now holds a similar position with the Continental Motors Corp, of Muskegon, Mich.

Announcement has been received that **W. H. Righter**, who formerly was designing engineer for the Kinner Airplane & Motor Corp., of Glendale, Calif., is now engine designer for the Myers & McNeil Co., of the same city.

Joseph Schaeffers, who is consulting engineer for Schlika Motors, of Berlin, Germany, is now in this Country as consulting engineer for the Lee Motors Corp., of Collegeville, Pa., manufacturer of aviation engines, in addition to serving the German company.

Lyle K. Snell has left the Eaton Axle & Spring Co., of Cleveland, and is now acting as consulting engineer at Detroit. His office is located at 669 Gladstone Avenue.

Frank S. Spring, formerly general manager of the Walter M. Murphy Co., of Pasadena, Calif., recently assumed new duties as engineer with the Hudson Motor Car Co., in Detroit.

William M. Stilger, having left his former position as general service manager of the Hudson Motor Car Co. of Illinois, in Chicago, is now service manager of the Histed Motor Co., of Milwaukee, distributor of Chrysler cars.

Walter F. Whiteman has accepted the position of research engineer with the Leopard Automobile Products Co., of Long Island City, N. Y. He was formerly riding-quality engineer for the Motor Rim Manufacturers Co., of Cleveland.

BETTER
Performance
WITH
Rich Valves
Wilcox Tappets
Wil-Rich Piston Rings
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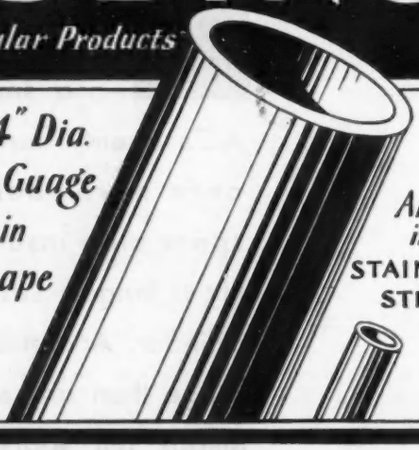
Manufactured by
Wilcox-Rich
CORPORATION
Detroit

WELDED STEEL
TUBING
and Tubular Products
¼" to 4" Dia.
9 to 22 Guage
Made in
Any Shape

Also
in
STAINLESS
STEEL
MICHIGAN
STEEL TUBE PRODUCTS COMPANY
BUFFALO STREET, DETROIT

S. A. E. Journal

JUNE, 1931

REPORTS OF DIVISIONS TO STANDARDS COMMITTEE

Standards Committee Meeting
Wednesday, June 17, 1931
at 10 o'clock
Greenbrier Hotel—Ball Room
White Sulphur Springs, W. Va.

THE SOCIETY OF AUTOMOTIVE ENGINEERS, INC.
29 WEST THIRTY-NINTH STREET
NEW YORK CITY

Reports of Divisions to Standards Committee

Standards Committee Meeting June 17, 1931

Greenbrier Hotel, White Sulphur Springs, W. Va.

IN this pamphlet are printed the reports that have been prepared for submission to the Standards Committee and to the Society by Divisions of the Standards Committee since the Annual Meeting last January.

All of the reports are submitted at this time for approval after having been considered carefully by the respective Divisions and given as wide publicity as possible by publication in the S.A.E. JOURNAL from month to month. The reports, as now presented, are believed to be in acceptable form, and any proposals should be only in the nature of important and carefully considered constructive changes.

Under the Standards Committee Regulations, these reports may be approved as presented, amended within limitations or referred back to the respective Divisions for sufficient reason. The action taken on them by the Standards Committee will be passed upon by the Council and the general business session of the Society and those approved will be published in the S.A.E. HANDBOOK.

Rejection or major changes in any of the reports will require that they be sent back to the Divisions that prepared them and that they cannot be passed upon again before the Semi-Annual Meeting of the Society next summer. In voting on the reports at the Standards Committee Meeting, the Regulations require that only members of the Standards Committee do so.

Aircraft Division

PERSONNEL

J. F. Hardecker, *Chairman*	Naval Aircraft Factory
Mac Short, *Vice-Chairman*	Stearman Aircraft Co.
Lieut. R. S. Barnaby, U. S. N.	Bureau of Aeronautics, Navy Department
John R. Cautley	Bendix Brake Co.
C. H. Colvin	Pioneer Instrument Co., Inc.
R. C. Eaton	Sikorsky Aviation Corp.
G. G. Emerson	Wright Aeronautical Corp.
C. B. Harper	Baltimore
Major C. W. Howard, U. S. A.	Materiel Division, Air Corps
Charles E. Kirkbride	Naval Aircraft Factory
I. M. Laddon	Consolidated Aircraft Corp.
K. M. Lane	Aircraft Development Corp.
B. J. Lemon	United States Rubber Co.
C. J. McCarthy	Chance Vought Corp.
L. C. Milburn	Glenn L. Martin Co.
Proctor Nichols	Alexander Aircraft Co.
C. T. Porter	Keystone Aircraft Corp.
W. L. Smith	National Air Transport, Inc.
Geo. I. Stich	Aero Supply Mfg. Co., Inc.
Edward Wallace	Cleveland Heights, Ohio
T. P. Wright	Curtiss Aeroplane & Motor Co., Inc.

Airplane Tire-Valves—High-Pressure Type

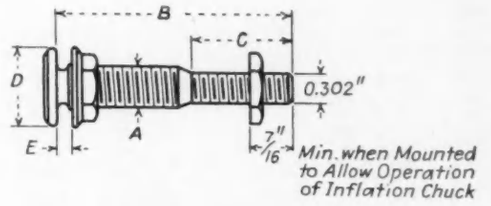
(*Proposed Revision to S.A.E. Recommended Practice*)

The Division recommends that this specification, p. 23 of the 1931 S.A.E. HANDBOOK, be revised by including the 12×4 high-pressure tire-size for valve No. 61.

Airplane Tire-Valves—Low-Pressure Type

(*Proposed S.A.E. Recommended Practice*)

The Division recommends adoption of the following specification as S.A.E. Recommended Practice.



VALVES FOR LOW-PRESSURE AIRPLANE-TIRES

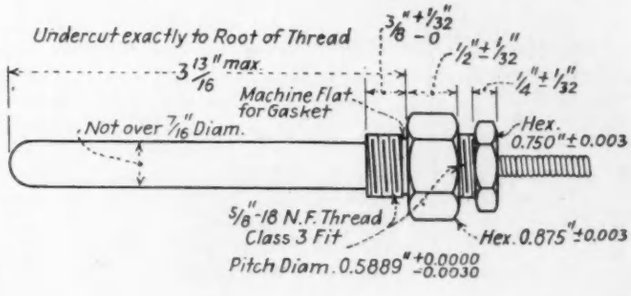
Valve No.[a]	A	B	C	D	E
90	0.406	2⅜	1 3/32	13/16	5/32
91	0.482	3⅛	1½	1 1/16	3/16

[a] Numbers refer to Tire & Rim Association standard.

Thermometer Bulbs

(*Proposed Revision of S.A.E. Standard*)

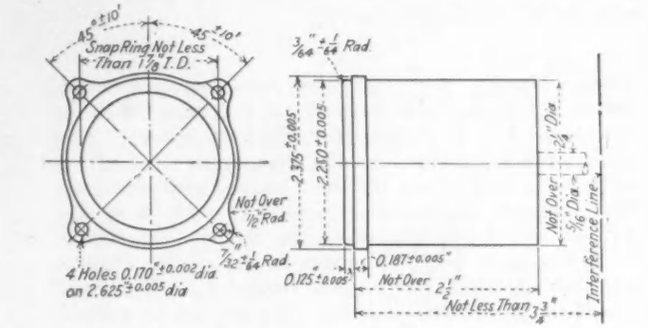
A Subdivision, of which Charles H. Colvin is chairman, has made a careful study of the dimensions given in the present S.A.E. specifications commencing on p. 13 of the 1931 edition of the S.A.E. HANDBOOK, in comparison with the dimensions included in the Army-Navy Standards and a

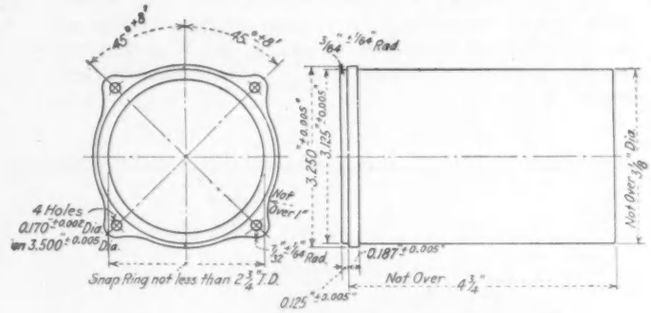

Undercut exactly to Root of Thread
3/8" +1/32 -0
1/2" ± 1/32
3 13/16" max.
Machine Flat for Gasket
1/4" ± 1/32
Not over 7/16" Diam.
Hex. 0.750" ± 0.003
5/8"-18 N.F. Thread Class 3 Fit
Hex. 0.875" ± 0.003
Pitch Diam. 0.5889" +0.0000 -0.0030

number of changes in the S.A.E. specifications were approved at a meeting of the Subdivision on April 13. These were reported to the Aircraft Division at its meeting on April 17 and the following revised specifications for the three subjects named above are accordingly recommended for approval and adoption by the Society.

Aircraft-Instrument Cases and Mountings

(Proposed Revision of S.A.E. Recommended Practice)

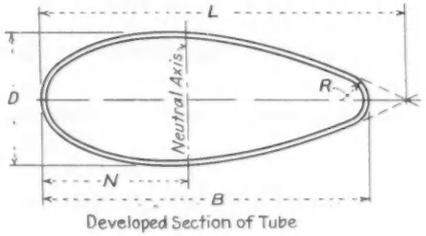

Snap Ring Not Less Than 1 7/8 I.D.
Not Over 1/8 Rad.
4 Holes 0.170" ±0.002 dia. on 2.625" ±0.005 dia
0.187" ±0.005"
Not Over 2 1/2"
Not Less Than 3 3/8"
Interference Line



Aircraft Structural Tubing

(Proposed S.A.E. Recommended Practice)

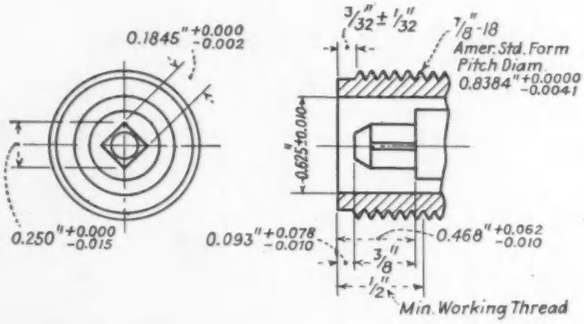
One of the most important subjects that the Aircraft Division has been working on is aircraft tubing of both round and streamline sections. A careful investigation that was made of the tubing dimensions most generally used by the aircraft manufacturers resulted in the preparation of the following tables of round structural tubing of various wall thicknesses. From this study was also worked out a standard series of streamline tubing sections together with the physical characteristics as shown in the accompanying tables. This proposal was then circularized among the tubing manufacturers and users preparatory to a final review of the report at the meeting of the Aircraft Division last April. Although some tubing sizes included in the tables are not used the Division feels that the accompanying recommendation should be adopted at this time as the basic standard and that it can be supplemented later by other tubing sizes which may be used in sufficient quantity to warrant their inclusion in a standard. The accompanying tables of dimensions for carbon-steel, alloy-steel and aluminum-alloy tubing are accordingly recommended by the Division for adoption as S.A.E. Recommended Practice.

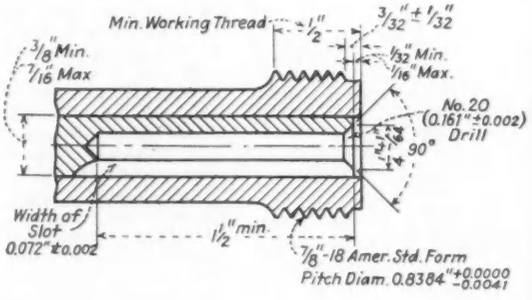


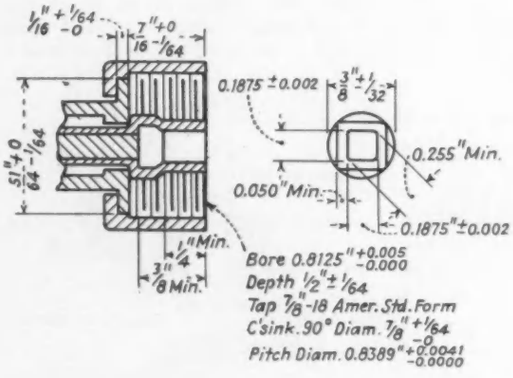
Developed Section of Tube

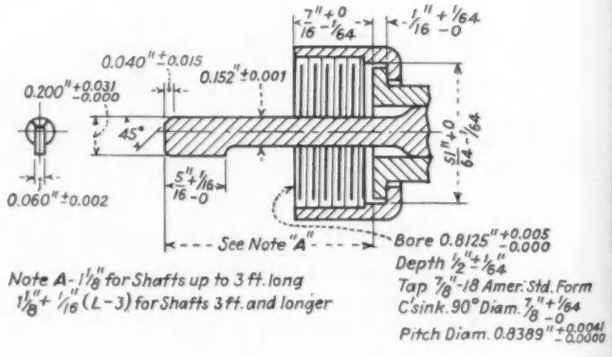
Tachometer Drive

(Proposed Revision of S.A.E. Standard)









Note A - 1 1/8" for Shafts up to 3 ft. long
1 1/8" + 1/16" (L - 3) for Shafts 3 ft. and longer

TABLE 1—STREAMLINE TUBING DIMENSIONS

Round Tubing, Diameter, Inches	*D*	*B*	*L*	*N*	*R*
2	1.143	2.697	2.857	1.286	0.217
2¼	1.286	3.034	3.214	1.446	0.244
2½	1.429	3.371	3.571	1.607	0.271
2¾	1.571	3.708	3.928	1.768	0.299
3	1.714	4.046	4.283	1.929	0.326
3¼	1.857	4.383	4.643	2.089	0.353
3½	2.000	4.720	5.000	2.250	0.380
3¾	2.143	5.057	5.357	2.411	0.407
4	2.286	5.394	5.714	2.571	0.434
4¼	2.428	5.731	6.071	2.732	0.461
4½	2.571	6.068	6.428	2.893	0.489
4¾	2.714	6.405	6.785	3.053	0.516
5	2.857	6.743	7.143	3.214	0.543

D (Max. width of streamline section) = 0.5714 × Diameter of Round Tube $L = 2.5 \times D$ $B = 0.944 \times L$ $R = 0.19 \times D$ $N = 0.45 \times L$

TABLE 2—PROGRESSIVE SECTION WIDTH DIMENSIONS—STREAMLINE TUBING

Round Tubing Diameters, In.

2		2¼		2½		2¾		3		3¼		3½		3¾		4		4¼		4½		4¾		5	
Distance from Nose	Section width	Distance from Nose	Section width	Distance from Nose	Section width	Distance from Nose	Section width	Distance from Nose	Section width	Distance from Nose	Section width	Distance from Nose	Section width	Distance from Nose	Section width	Distance from Nose	Section width	Distance from Nose	Section width	Distance from Nose	Section width	Distance from Nose	Section width	Distance from Nose	Section width
0.036	0.297	0.040	0.334	0.045	0.371	0.049	0.409	0.054	0.446	0.058	0.483	0.063	0.520	0.067	0.557	0.071	0.594	0.076	0.631	0.080	0.669	0.085	0.706	0.089	0.743
0.071	0.424	0.080	0.477	0.089	0.530	0.098	0.583	0.107	0.636	0.116	0.689	0.125	0.742	0.134	0.795	0.143	0.848	0.152	0.901	0.161	0.954	0.170	1.007	0.179	1.060
0.143	0.600	0.161	0.675	0.179	0.750	0.196	0.825	0.214	0.900	0.232	0.975	0.250	1.050	0.268	1.125	0.286	1.200	0.304	1.275	0.321	1.350	0.339	1.425	0.357	1.500
0.214	0.727	0.241	0.818	0.268	0.909	0.295	0.999	0.321	1.090	0.348	1.181	0.375	1.272	0.402	1.363	0.429	1.454	0.455	1.544	0.482	1.635	0.509	1.726	0.536	1.817
0.286	0.823	0.321	0.926	0.357	1.029	0.393	1.131	0.429	1.234	0.464	1.337	0.500	1.440	0.536	1.543	0.571	1.646	0.607	1.748	0.643	1.851	0.679	1.954	0.714	2.057
0.357	0.897	0.402	1.009	0.446	1.121	0.491	1.234	0.536	1.346	0.580	1.458	0.625	1.570	0.670	1.682	0.714	1.794	0.759	1.906	0.804	2.018	0.848	2.131	0.893	2.243
0.429	0.955	0.482	1.075	0.536	1.194	0.589	1.314	0.643	1.433	0.696	1.553	0.750	1.672	0.804	1.791	0.857	1.911	0.911	2.030	0.964	2.150	1.018	2.269	1.071	2.388
0.500	1.003	0.562	1.129	0.625	1.254	0.688	1.380	0.750	1.505	0.812	1.630	0.875	1.756	0.938	1.881	1.000	2.007	1.062	2.132	1.125	2.258	1.187	2.383	1.250	2.508
0.571	1.041	0.643	1.171	0.714	1.301	0.786	1.432	0.857	1.561	0.929	1.692	1.000	1.822	1.071	1.952	1.143	2.082	1.214	2.212	1.286	2.342	1.357	2.473	1.429	2.603
0.714	1.096	0.804	1.233	0.893	1.370	0.982	1.507	1.071	1.644	1.161	1.781	1.250	1.918	1.339	2.055	1.429	2.192	1.518	2.329	1.607	2.466	1.696	2.603	1.786	2.740
0.857	1.129	0.964	1.270	1.071	1.411	1.179	1.553	1.286	1.694	1.393	1.835	1.500	1.976	1.607	2.117	1.714	2.258	1.821	2.399	1.928	2.540	2.036	2.682	2.143	2.823
1.000	1.143	1.125	1.286	1.250	1.429	1.375	1.571	1.500	1.714	1.625	1.857	1.750	2.000	1.875	2.143	2.000	2.286	2.125	2.428	2.250	2.571	2.375	2.714	2.500	2.857
1.143	1.137	1.286	1.279	1.429	1.421	1.571	1.564	1.714	1.706	1.857	1.848	2.000	1.990	2.143	2.132	2.286	2.274	2.428	2.416	2.571	2.558	2.714	2.701	2.857	2.843
1.286	1.119	1.446	1.259	1.607	1.399	1.768	1.538	1.929	1.678	2.089	1.818	2.250	1.958	2.411	2.098	2.571	2.238	2.732	2.377	2.893	2.517	3.053	2.657	3.214	2.797
1.429	1.086	1.607	1.221	1.786	1.357	1.964	1.493	2.143	1.629	2.321	1.764	2.500	1.900	2.678	2.036	2.857	2.171	3.036	2.307	3.214	2.443	3.393	2.578	3.571	2.714
1.571	1.040	1.768	1.170	1.964	1.300	2.161	1.430	2.357	1.560	2.553	1.690	2.750	1.820	2.946	1.950	3.143	2.080	3.339	2.210	3.536	2.340	3.732	2.470	3.928	2.600
1.714	0.984	1.929	1.107	2.143	1.230	2.357	1.353	2.571	1.476	2.786	1.599	3.000	1.722	3.214	1.845	3.428	1.968	3.643	2.091	3.857	2.214	4.071	2.337	4.286	2.460
1.857	0.915	2.089	1.030	2.321	1.144	2.553	1.259	2.786	1.373	3.018	1.488	3.250	1.602	3.482	1.716	3.714	1.831	3.946	1.945	4.178	2.060	4.410	2.174	4.643	2.288
2.000	0.837	2.250	0.941	2.500	1.046	2.750	1.150	3.000	1.255	3.250	1.359	3.500	1.464	3.750	1.569	4.000	1.673	4.250	1.778	4.500	1.882	4.750	1.987	5.000	2.091
2.143	0.746	2.411	0.840	2.678	0.933	2.946	1.026	3.214	1.119	3.482	1.213	3.750	1.306	4.018	1.399	4.286	1.492	4.553	1.586	4.821	1.679	5.089	1.772	5.357	1.866
2.286	0.642	2.571	0.723	2.857	0.803	3.143	0.883	3.428	0.963	3.714	1.044	4.000	1.124	4.286	1.204	4.571	1.285	4.857	1.365	5.143	1.445	5.428	1.525	5.714	1.606
2.429	0.527	2.732	0.593	3.036	0.659	3.339	0.724	3.643	0.790	3.946	0.856	4.250	0.922	4.553	0.988	4.857	1.054	5.160	1.119	5.464	1.185	5.768	1.251	6.071	1.317
2.571	0.386	2.893	0.435	3.214	0.483	3.536	0.531	3.857	0.579	4.178	0.628	4.500	0.676	4.821	0.724	5.143	0.773	5.464	0.821	5.785	0.869	6.107	0.917	6.428	0.966
2.714	0.217	3.053	0.244	3.393	0.271	3.732	0.299	4.071	0.326	4.410	0.353	4.750	0.380	5.089	0.407	5.428	0.434	5.767	0.461	6.107	0.489	6.446	0.516	6.785	0.543

TABLE 3—ALUMINUM ALLOY, ROUND SIZES

Outside Diameter, In.	Wall Thickness B. W. G.												
	24 (0.022)	22 (0.028)	21 (0.032)	20 (0.035)	19 (0.042)	18 (0.049)	17 (0.058)	16 (0.065)	15 (0.072)	14 (0.083)	13 (0.095)	12 (0.109)	11 (0.120)
1/4	X	X											
5/16	X	X											
3/8	X	X											
7/16	X	X											
1/2	X	X	X		X								
5/8	.....	X	X	.....	X	.....	X						
3/4	.....	X	X	.....	X	.....	X						
7/8	.....	X	X	.....	X	.....	X						
1	.....	X	X	.....	X	.....	X						
1 1/8	.....	.....	X	X	X	.....	X						
1 1/4	.....	.....	X	X	X	.....	X						
1 3/8	.....	.....	.....	.....	X	X	X						
1 1/2	.....	.....	.....	.....	X	X	X						
1 5/8	.....	.....	.....	.....	X	X	X						
1 3/4	.....	.....	.....	.....	.....	X	X						
1 7/8	.....	.....	.....	.....	.....	.....	X	X					
2	.....	.....	S	.....	S	.....	X	X					
2 1/8	.....	.....	.....	.....	.....	.....	X	X					
2 1/4	.....	.....	S	.....	S	.....	.....	X	X	.....	X	.....	X
2 3/8	.....	.....	.....	.....	.....	.....	.....	X	X	.....	.....	.....	X
2 1/2	.....	.....	.....	.....	S	.....	S	.....	X	X	.....	.....	X
2 5/8	.....	.....	.....	.....	.....	.....	.....	.....	X	X	.....	.....	X
2 3/4	.....	.....	.....	.....	S	.....	S	.....	.....	X	X	.....	X
2 7/8	.....	.....	.....	.....	.....	.....	.....	.....	.....	X	X	.....	X
3	.....	.....	.....	.....	S	.....	S	.....	.....	X	X	.....	X
3 1/4	.....	.....	.....	.....	.....	S	.....	S	.....	.....	X	X	X
3 1/2	.....	.....	.....	.....	.....	.....	S	.....	S	.....	X	X	X
3 3/4	.....	.....	.....	.....	.....	.....	S	.....	S	.....	.....	X	X
4	.....	.....	.....	.....	.....	.....	.....	S	.....	S	.....	.....	S
4 1/4	.....	.....	.....	.....	.....	.....	.....	S	.....	.....	S	.....	
4 1/2	.....	.....	.....	.....	.....	.....	.....	.....	S	.....	S	.....	S
4 3/4	.....	.....	.....	.....	.....	.....	.....	.....	S	.....	S	.....	
5	.....	.....	.....	.....	.....	.....	.....	.....	.....	S	.....	.....	S

S denotes sizes used for streamline sections.

TABLE 4—CARBON STEEL, ROUND SIZES

(Supplement to S.A.E. drawing 1–34–1 dated April 17, 1931)

Outside diameter, In.	Wall Thickness B. W. G.								
	24 (0.022)	22 (0.028)	20 (0.035)	18 (0.049)	17 (0.058)	16 (0.065)	14 (0.083)	13 (0.095)	11 (0.120)
5/16	X	X	X						
1/4	X	X	X	X					
5/16	.....	X	X	X	X				
3/8	.....	.....	X	X	X	X			
1/2	.....	.....	X	X	X	X	X		
5/8	.....	.....	X	X	X	X	X		
3/4	.....	.....	X	X	X	X	X		
7/8	.....	.....	X	X	X	X	X		
1	.....	.....	X	X	X	X	X	X	
1 1/8	.....	.....	X	X	X	X	.....	X	
1 1/4	.....	.....	X	X	X	X	.....	X	
1 3/8	.....	.....	X	X	X	X	.....	X	
1 1/2	.....	.....	X	X	X	X	X	X	X
1 5/8	.....	.....	.....	.....	X	X	.....	.....	
1 3/4	.....	.....	.....	.....	X	X	.....	X	X
1 7/8	.....	.....	.....	.....	X	X	.....	.....	
2	.....	.....	S	.....	X	X	X	X	X
2 1/4	.....	.....	.....	S	.....	X	.....	X	
2 1/2	.....	.....	.....	S	.....	X	.....	.....	X
2 3/4	.....	.....	.....	S	.....	S	.....	S	
3	.....	.....	.....	S	.....	S	.....	.....	S
3 1/4	.....	.....	.....	.....	S	.....	S	.....	
3 1/2	.....	.....	.....	.....	S	.....	S	.....	S
3 3/4	.....	.....	.....	.....	S	.....	S	.....	
4	.....	.....	.....	.....	S	S	.....	S	S
4 1/4	.....	.....	.....	.....	.....	S	.....	S	
4 1/2	.....	.....	.....	.....	.....	S	.....	S	S
4 3/4	.....	.....	.....	.....	.....	S	.....	S	
5	.....	.....	.....	.....	.....	S	.....	S	S

S denotes sizes used for streamline sections.

TABLE 5—ALLOY STEEL, ROUND SIZES

(Supplement to S.A.E. drawing 1–34–1 dated April 17, 1931)

Outside diameter, In.	Wall Thickness B. W. G.									
	24 (0.022)	22 (0.028)	20 (0.035)	18 (0.049)	17 (0.058)	16 (0.065)	14 (0.083)	13 (0.095)	11 (0.120)	3/16 (0.187)
5/16	X	X	X							
1/4	X	X	X	X						
5/16	.....	X	X	X	X					
3/8	.....	.....	X	X	X	X				
1/2	.....	.....	X	X	X	X				
5/8	.....	.....	X	X	X	X				
3/4	.....	.....	X	X	X	X	X			
7/8	.....	.....	X	X	X	X	X			
1	.....	.....	X	X	X	X	X	X	X	
1 1/8	.....	.....	X	X	X	X	X			
1 1/4	.....	.....	X	X	X	X	X	X	X	
1 3/8	.....	.....	X	X	X	X	X			
1 1/2	.....	.....	X	X	X	X	X	X	X	
1 5/8	.....	.....	.....	X	X	X				
1 3/4	.....	.....	.....	.....	X	X	X	X	X	
1 7/8	.....	.....	.....	.....	X	X				
2	.....	.....	S	.....	X	X	X	X	X	
2 1/4	.....	.....	.....	S	.....	X	.....	X	X	X
2 1/2	.....	.....	.....	S	.....	X	X	X	X	
2 3/4	.....	.....	.....	S	.....	X	.....	X	X	X
3	.....	.....	.....	S	.....	S	X	X	X	
3 1/4	.....	.....	.....	.....	S	.....	S	.....	.....	
3 1/2	.....	.....	.....	.....	S	.....	S	.....	S	
3 3/4	.....	.....	.....	.....	S	.....	S	.....	.....	
4	.....	.....	.....	.....	S	S	.....	S	S	
4 1/4	.....	.....	.....	.....	.....	S	.....	S	.....	
4 1/2	.....	.....	.....	.....	.....	S	.....	S	S	
4 3/4	.....	.....	.....	.....	.....	S	.....	S	.....	
5	.....	.....	.....	.....	.....	S	.....	S	S	

S denotes sizes used for streamline sections.

TABLE 6—ROUND TUBING CHARACTERISTICS

Outside Diameter, In.	Thickness, B. W. G. In.	Section Area, Sq. In.	Weight Per Foot, Lb.		ROUND		
			Steel	Aluminum Alloy	Moment of Inertia *I*	Section Modulus *Z*	Radius of Gyration *K*
0.1875 (3/16)	24—0.022	0.01144	0.039	0.014	0.000040	0.000425	0.05903
0.1875	22—0.028	0.01403	0.048	0.017	0.000046	0.000491	0.05725
0.1875	20—0.035	0.01677	0.057	0.020	0.000051	0.000547	0.05532
0.2500 (1/4)	24—0.022	0.01576	0.054	0.019	0.000103	0.000827	0.08098
0.2500	22—0.028	0.01953	0.067	0.023	0.000122	0.000978	0.07911
0.2500	20—0.035	0.02364	0.081	0.028	0.000140	0.001122	0.07701
0.2500	18—0.049	0.03094	0.105	0.037	0.000165	0.001324	0.07314
0.3125 (5/16)	24—0.022	0.02008	0.068	0.024	0.000213	0.001363	0.10300
0.3125	22—0.028	0.02503	0.085	0.030	0.000256	0.001636	0.10107
0.3125	20—0.035	0.03051	0.104	0.037	0.000298	0.001910	0.09888
0.3125	18—0.049	0.04056	0.138	0.049	0.000364	0.002331	0.09475
0.3125	17—0.058	0.04637	0.158	0.056	0.000395	0.002527	0.09229
0.375 (3/8)	24—0.022	0.02440	0.083	0.029	0.000381	0.002035	0.12505
0.375	22—0.028	0.030524	0.104	0.037	0.000462	0.002463	0.12309
0.375	20—0.035	0.03739	0.127	0.045	0.000546	0.002912	0.12084
0.375	18—0.049	0.05018	0.171	0.060	0.000632	0.003636	0.11655
0.375	17—0.058	0.05776	0.197	0.069	0.000750	0.003999	0.11393
0.375	16—0.065	0.06330	0.216	0.076	0.000794	0.004234	0.11199
0.4375 (7/16)	24—0.022	0.02872	0.098	0.034	0.000621	0.002811	0.14710
0.4375	22—0.028	0.03602	0.123	0.043	0.000759	0.003470	0.14512
0.500 (1/2)	24—0.022	0.03304	0.112	0.040	0.00095	0.00378	0.16918
0.500	22—0.028	0.04152	0.142	0.053	0.00116	0.00464	0.167218
0.500	21—0.032	0.04705	0.160	0.056	0.00129	0.00518	0.16585
0.500	20—0.035	0.05113	0.174	0.061	0.00139	0.00556	0.16487
0.500	19—0.042	0.06043	0.206	0.073	0.00160	0.00639	0.16261
0.500	18—0.049	0.06943	0.236	0.083	0.00179	0.00714	0.16039
0.500	17—0.058	0.08054	0.275	0.097	0.00200	0.00800	0.15761
0.500	16—0.065	0.08883	0.303	0.107	0.00215	0.00859	0.15550
0.500	14—0.083	0.10873	0.371	0.131	0.00246	0.00983	0.15032
0.625 (5/8)	22—0.028	0.05252	0.179	0.063	0.00234	0.00750	0.21130
0.625	21—0.032	0.05962	0.203	0.072	0.00263	0.00841	0.20996
0.625	20—0.035	0.06487	0.221	0.078	0.00283	0.00906	0.20896
0.625	19—0.042	0.07693	0.262	0.092	0.00329	0.01051	0.20666
0.625	18—0.049	0.08867	0.302	0.106	0.00370	0.01185	0.20438
0.625	17—0.058	0.10331	0.352	0.124	0.00419	0.01342	0.20151
0.625	16—0.065	0.11435	0.390	0.137	0.00454	0.01454	0.19932
0.625	14—0.083	0.14133	0.482	0.170	0.00531	0.01670	0.19386
0.750 (3/4)	22—0.028	0.06351	0.217	0.076	0.00414	0.01105	0.25546
0.750	21—0.032	0.07218	0.246	0.087	0.00466	0.01243	0.25410
0.750	20—0.035	0.07862	0.268	0.094	0.00504	0.01343	0.25309
0.750	19—0.042	0.09342	0.318	0.112	0.00587	0.01566	0.25075
0.750	18—0.049	0.10791	0.368	0.129	0.00666	0.01776	0.24844
0.750	17—0.058	0.12609	0.430	0.151	0.00760	0.02027	0.24551
0.750	16—0.065	0.13988	0.477	0.168	0.00828	0.02208	0.24327
0.750	14—0.083	0.17392	0.593	0.209	0.00982	0.02619	0.23764
0.875 (7/8)	22—0.028	0.07451	0.254	0.089	0.00669	0.01529	0.29962
0.875	21—0.032	0.08475	0.289	0.102	0.00754	0.01723	0.29826
0.875	20—0.035	0.09236	0.315	0.111	0.00816	0.01865	0.29724
0.875	19—0.042	0.10990	0.375	0.132	0.00956	0.02184	0.29488
0.875	18—0.049	0.12715	0.433	0.153	0.01088	0.02487	0.29255
0.875	17—0.058	0.14887	0.507	0.179	0.01248	0.02853	0.28958
0.875	16—0.065	0.16541	0.564	0.198	0.01365	0.03121	0.28729
0.875	14—0.083	0.20652	0.704	0.248	0.01637	0.03742	0.28155
1.000	22—0.028	0.08550	0.291	0.103	0.01011	0.02021	0.34380
1.000	21—0.032	0.09731	0.332	0.117	0.01141	0.02282	0.34243
1.000	20—0.035	0.10611	0.362	0.127	0.01237	0.02474	0.34140
1.000	19—0.042	0.12641	0.431	0.152	0.01453	0.02905	0.33903
1.000	18—0.049	0.14640	0.499	0.176	0.01659	0.03319	0.33667
1.000	17—0.058	0.17164	0.585	0.206	0.01911	0.03822	0.33368
1.000	16—0.065	0.19093	0.651	0.229	0.02097	0.04193	0.33137
1.000	14—0.083	0.23911	0.815	0.287	0.02534	0.05068	0.32553
1.000	13—0.095	0.27010	0.921	0.324	0.02796	0.05591	0.32172
1.000	11—0.120	0.33175	1.131	0.398	0.03271	0.06542	0.31398
1.125 (1 1/8)	21—0.032	0.10988	0.375	0.132	0.01642	0.02920	0.38659
1.125	20—0.035	0.11985	0.409	0.144	0.01782	0.03168	0.38557

TABLE 6—ROUND TUBING CHARACTERISTICS (*Concluded*)

Outside Diameter, In.	Thickness, B. W. G. In.	Section Area, Sq. In.	Weight Per Foot, Lb.		ROUND		
			Steel	Aluminum Alloy	Moment of Inertia *I*	Section Modulus *Z*	Radius of Gyration *K*
1.125	19—0.042	0.14290	0.487	0.171	0.02098	0.03730	0.38319
1.125	18—0.049	0.16564	0.565	0.199	0.02402	0.04270	0.38082
1.125	17—0.058	0.19442	0.663	0.233	0.02775	0.04933	0.37789
1.125	16—0.065	0.21646	0.738	0.260	0.03052	0.05425	0.37547
1.125	14—0.083	0.27170	0.926	0.326	0.03711	0.06597	0.36957
1.125	13—0.095	0.30741	1.048	0.369	0.04111	0.07309	0.36571
1.250 (1¼)	21—0.032	0.12245	0.417	0.147	0.02272	0.03636	0.43078
1.250	20—0.035	0.13360	0.455	0.160	0.02467	0.03948	0.42975
1.250	19—0.042	0.15939	0.543	0.191	0.02911	0.04658	0.42735
1.250	18—0.049	0.18488	0.630	0.222	0.03339	0.05342	0.42497
1.250	17—0.058	0.21720	0.740	0.261	0.03867	0.06187	0.42194
1.250	16—0.065	0.24198	0.825	0.290	0.04260	0.06816	0.41959
1.250	14—0.083	0.30430	1.037	0.365	0.05207	0.08330	0.41364
1.250	13—0.095	0.34471	1.175	0.414	0.05787	0.09259	0.40974
1.250	11—0.120	0.42600	1.452	0.511	0.06876	0.11002	0.40176
1.375 (1⅜)	20—0.035	0.14734	0.502	0.177	0.03309	0.04814	0.47392
1.375	19—0.042	0.17590	0.600	0.211	0.03910	0.05688	0.47152
1.375	18—0.049	0.20412	0.696	0.245	0.04492	0.06534	0.46913
1.375	17—0.058	0.23997	0.818	0.288	0.05213	0.07583	0.46608
1.375	16—0.065	0.26751	0.912	0.321	0.05753	0.08367	0.46372
1.375	14—0.083	0.33689	1.149	0.404	0.07059	0.10267	0.45774
1.375	13—0.095	0.38202	1.302	0.458	0.07867	0.11443	0.45379
1.500 (1½)	20—0.035	0.16109	0.549	0.193	0.04324	0.05765	0.51810
1.500	19—0.042	0.19238	0.656	0.231	0.05116	0.06822	0.51569
1.500	18—0.049	0.22336	0.761	0.268	0.05885	0.07847	0.51330
1.500	17—0.058	0.26275	0.896	0.315	0.06840	0.09121	0.51024
1.500	16—0.065	0.29303	0.999	0.352	0.07558	0.10078	0.50787
1.500	14—0.083	0.36949	1.260	0.443	0.09305	0.12407	0.50184
1.500	13—0.095	0.41933	1.430	0.503	0.10394	0.13859	0.49788
1.500	11—0.120	0.52025	1.774	0.624	0.12478	0.16638	0.48974
1.625 (1⅝)	19—0.042	0.20887	0.712	0.251	0.06547	0.08058	0.55987
1.625	18—0.049	0.24261	0.827	0.291	0.07540	0.09279	0.55747
1.625	17—0.058	0.28553	0.973	0.343	0.08776	0.10801	0.55440
1.625	16—0.065	0.31856	1.086	0.382	0.09707	0.11948	0.55202
1.750 (1¾)	18—0.049	0.26185	0.893	0.314	0.09478	0.10832	0.60154
1.750	17—0.058	0.30830	1.051	0.370	0.11046	0.12624	0.59856
1.750	16—0.065	0.34408	1.173	0.413	0.12230	0.13977	0.59618
1.750	14—0.083	0.43467	1.482	0.522	0.15136	0.17299	0.59010
1.750	13—0.095	0.49394	1.684	0.593	0.16967	0.19391	0.58609
1.750	11—0.120	0.61450	2.095	0.737	0.20519	0.2345	0.57785
1.875 (1⅞)	17—0.058	0.33108	1.129	0.397	0.13677	0.14589	0.64273
1.875	16—0.065	0.36961	1.260	0.444	0.15155	0.16166	0.64034

TABLE 7—ROUND AND STREAMLINE TUBING CHARACTERISTICS

Outside Diameter, In.	Thickness, B. W G. In.	Section Area, Sq. In.	Weight Per Foot, Lb.		ROUND			STREAMLINE RATIO 2½ to 1		
			Steel	Aluminum Alloy	Moment of Inertia *I*	Section Modulus *Z*	Radius of Gyration *K*	Moment of Inertia *I*	Section Modulus *Z*	Radius of Gyration *K*
2.000	21—0.032	0.19785	0.675	0.237	0.09581	0.09581	0.69589	0.03449	0.06036	0.41753
2.000	20—0.035	0.21606	0.737	0.259	0.10432	0.10432	0.69484	0.03756	0.06722	0.41690
2.000	19—0.042	0.25835	0.881	0.310	0.12386	0.12386	0.69242	0.04459	0.07803	0.41545
2.000	17—0.058	0.35386	1.206	0.425	0.16696	0.16696	0.68691	0.06011	0.10518	0.41215
2.000	16—0.065	0.39513	1.347	0.474	0.18514	0.18514	0.68451	0.06665	0.11664	0.41071
2.000	14—0.083	0.49986	1.704	0.560	0.23005	0.23005	0.67840	0.08282	0.14493	0.40704
2.000	13—0.095	0.56855	1.938	0.682	0.25855	0.25855	0.67436	0.09308	0.16287	0.40462
2.000	11—0.120	0.70874	2.416	0.850	0.31439	0.31439	0.66603	0.11318	0.19807	0.39962
2.125 (2⅛)	17—0.058	0.37663	1.284	0.452	0.20130	0.18946	0.73108			
2.125	16—0.065	0.42066	1.434	0.505	0.22336	0.21022	0.72868			
2.250 (2¼)	21—0.032	0.22298	0.760	0.268	0.13715	0.12191	0.78426	0.04937	0.07680	0.47056
2.250	19—0.042	0.29134	0.993	0.350	0.17761	0.16507	0.78079	0.06394	0.99458	0.46847
2.250	18—0.049	0.33882	1.155	0.407	0.20527	0.18246	0.77856	0.07390	0.11495	0.46702
2.250	16—0.065	0.44619	1.521	0.535	0.26651	0.23690	0.77286	0.09594	0.14925	0.46372
2.250	15—0.072	0.49265	1.680	0.591	0.29245	0.25994	0.77045	0.10528	0.16376	0.46227
2.250	13—0.095	0.64317	2.193	0.772	0.37408	0.33252	0.76265	0.13467	0.20948	0.45759
2.250	11—0.120	0.80300	2.738	0.964	0.45682	0.40607	0.75426	0.16446	0.25582	0.45256
2.250	3/16—0.1875	1.21492	4.142	1.458	0.65136	0.57898	0.73222	0.23449	0.36476	0.43933
2.375 (2⅜)	16—0.065	0.47171	1.608	0.566	0.31489	0.26517	0.81703			
2.375	15—0.072	0.52092	1.776	0.625	0.34570	0.29112	0.81463			
2.375	11—0.120	0.85011	2.898	1.020	0.54189	0.45633	0.79839			
2.500 (2½)	19—0.042	0.32433	1.106	0.389	0.24501	0.19601	0.86916	0.08820	0.12349	0.52150
2.500	18—0.049	0.37730	1.286	0.453	0.28344	0.22675	0.86673	0.10204	0.14285	0.52004
2.500	17—0.058	0.44496	1.517	0.534	0.33187	0.26550	0.86362	0.11947	0.16727	0.51817
2.500	16—0.065	0.49724	1.695	0.597	0.36879	0.29503	0.86121	0.13276	0.18587	0.51673
2.500	15—0.072	0.54920	1.872	0.659	0.40506	0.32405	0.85881	0.14582	0.204215	0.51528
2.500	14—0.083	0.63024	2.149	0.756	0.46077	0.36861	0.85504	0.16588	0.23222	0.51302
2.500	13—0.095	0.71778	2.447	0.861	0.51976	0.41581	0.85096	0.187011	0.26196	0.51058
2.500	11—0.120	0.89724	3.059	1.077	0.63691	0.50953	0.84252	0.22928	0.32100	0.50551
2.625 (2⅝)	15—0.072	0.57748	1.969	0.692	0.470854	0.35875	0.90298			
2.625	14—0.083	0.66283	2.260	0.795	0.53596	0.40855	0.89921			
2.625	11—0.120	0.94436	3.219	1.133	0.74244	0.56567	0.88667			
2.750 (2¾)	19—0.042	0.35732	1.218	0.429	0.32761	0.23826	0.95754	0.11794	0.15010	0.57452
2.750	18—0.049	0.41579	1.417	0.499	0.37929	0.27585	0.95511	0.13655	0.17379	0.57307
2.750	17—0.058	0.49052	1.672	0.589	0.44454	0.32331	0.95199	0.16003	0.20368	0.57119
2.750	16—0.065	0.54829	1.869	0.658	0.49438	0.35954	0.94958	0.17798	0.22651	0.56975
2.750	14—0.083	0.69543	2.371	0.835	0.61891	0.45012	0.94338	0.22280	0.28358	0.56613
2.750	13—0.095	0.79239	2.701	0.951	0.69909	0.50843	0.93928	0.25168	0.32031	0.56357
2.750	11—0.120	0.99149	3.380	1.189	0.85904	0.62476	0.93081	0.30925	0.39360	0.55849
2.750	3/16—0.1875	1.50944	5.146	1.811	1.24558	0.90588	0.90840	0.44841	0.57070	0.54504
2.875 (2⅞)	14—0.083	0.72802	2.482	0.874	0.71002	0.49393	0.98755			
2.875	13—0.095	0.82970	2.828	0.996	0.80246	0.55824	0.98345			
2.875	11—0.120	1.03861	3.541	1.246	0.98725	0.68679	0.97497			
3.000	19—0.042	0.39030	1.331	0.468	0.42696	0.28464	1.04592	0.15371	0.17932	0.62755
3.000	18—0.049	0.45427	1.549	0.545	0.49463	0.32976	1.04348	0.17806	0.20775	0.62609
3.000	17—0.058	0.53607	1.828	0.643	0.58021	0.38681	1.04036	0.20887	0.24369	0.62422
3.000	16—0.065	0.59934	2.043	0.719	0.64567	0.43045	1.03793	0.23244	0.27118	0.62276
3.000	14—0.083	0.76062	2.593	0.913	0.80965	0.53977	1.03174	0.29147	0.34005	0.61904
3.000	13—0.095	0.86700	2.956	1.040	0.91556	0.61028	1.02762	0.32960	0.38444	0.61657
3.000	11—0.120	1.08574	3.702	1.303	1.12765	0.75176	1.01911	0.40595	0.47361	0.61147
3.250 (3¼)	18—0.049	0.49276	1.680	0.591	0.63127	0.38847	1.13216	0.22726	0.24474	0.67929
3.250	17—0.058	0.58163	1.983	0.698	0.74100	0.45600	1.12873	0.26676	0.28728	0.67724
3.250	16—0.065	0.65039	2.217	0.781	0.82506	0.50773	1.12633	0.29702	0.31987	0.67578
3.250	14—0.083	0.82581	2.815	0.991	1.03605	0.63757	1.12009	0.37298	0.40167	0.67205
3.250	13—0.095	0.94162	3.210	1.129	1.17267	0.72164	1.11598	0.42216	0.45463	0.66959
3.250	12—0.109	1.07559	3.667	1.291	1.32805	0.81726	1.11118	0.47809	0.51487	0.66671
3.250	11—0.120	1.17999	4.023	1.416	1.44715	0.89061	1.10743	0.52097	0.56108	0.66446
3.500 (3½)	17—0.058	0.62718	2.138	0.753	0.92906	0.53089	1.21710	0.33446	0.33446	0.73026
3.500	15—0.072	0.77540	2.643	0.931	1.13948	0.65113	1.21225	0.41021	0.41021	0.72735
3.500	14—0.083	0.89099	3.038	1.069	1.30116	0.74352	1.20948	0.46842	0.46842	0.72569
3.500	13—0.095	1.01623	3.465	1.219	1.47392	0.84224	1.20432	0.53060	0.53061	0.72259
3.500	12—0.109	1.16119	3.959	1.393	1.67078	0.95473	1.19951	0.60148	0.60148	0.71971
3.500	11—0.120	1.27423	4.344	1.529	1.82196	1.04112	1.19576	0.65591	0.65591	0.71746

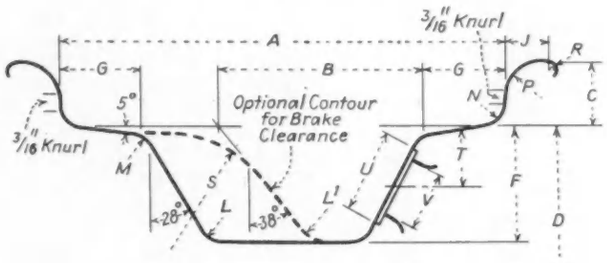
TABLE 7—ROUND AND STREAMLINE TUBING CHARACTERISTICS (*Concluded*)

Outside Diameter, In.	Thickness, B. W. G. In.	Section Area, Sq. In.	Weight Per Foot, Lb.		ROUND			STREAMLINE RATIO 2½ to 1		
			Steel	Aluminum Alloy	Moment of Inertia *I*	Section Modulus *Z*	Radius of Gyration *K*	Moment of Inertia *I*	Section Modulus *Z*	Radius of Gyration *K*
3.750 (3¾)	17—0.058	0.67273	2.293	0.807	1.14652	0.61148	1.30548	0.41275	0.38523	0.78329
3.750	15—0.072	0.83195	2.836	0.998	1.40733	0.75057	1.30062	0.50664	0.47286	0.78037
3.750	14—0.083	0.95618	3.260	1.147	1.60803	0.85762	1.29681	0.57889	0.54030	0.77809
3.750	12—0.109	1.24680	4.251	1.496	2.06794	1.10290	1.28786	0.74446	0.69483	0.77272
3.750	11—0.120	1.36848	4.665	1.642	2.25651	1.20347	1.28410	0.81234	0.75819	0.77046
4.000	17—0.058	0.71828	2.449	0.862	1.39551	0.69775	1.39386	0.50238	0.43958	0.83632
4.000	16—0.065	0.80354	2.739	0.964	1.55570	0.77785	1.39142	0.56005	0.49005	0.83485
4.000	14—0.083	1.02137	3.482	1.226	1.95972	0.97986	1.38518	0.70550	0.61731	0.83111
4.000	13—0.095	1.16546	3.973	1.399	2.22282	1.11141	1.38103	0.80022	0.70019	0.82862
4.000	11—0.120	1.46273	4.987	1.755	2.75520	1.37760	1.37244	0.99187	0.86789	0.82346
4.250 (4¼)	16—0.065	0.85460	2.914	1.026	1.87139	0.88066	1.47980	0.67370	0.55482	0.88788
4.250	13—0.095	1.24007	4.228	1.488	2.67747	1.25999	1.46940	0.96389	0.79379	0.88164
4.500 (4½)	16—0.065	0.90564	3.088	1.087	2.22714	0.98984	1.56818	0.80177	0.62360	0.94091
4.500	15—0.072	1.00159	3.415	1.202	2.45545	1.09131	1.56574	0.88396	0.68753	0.93944
4.500	13—0.095	1.31468	4.482	1.578	3.19025	1.41789	1.55776	1.14849	0.89327	0.93466
4.500	11—0.120	1.65122	5.629	1.981	3.96269	1.76120	1.54914	1.42657	1.10956	0.92948
4.750 (4¾)	16—0.065	0.95670	3.262	1.148	2.62535	1.10541	1.65656	0.94513	0.69641	0.99394
4.750	15—0.072	1.05814	3.607	1.270	2.89519	1.21903	1.65412	1.04227	0.76799	0.99247
4.750	13—0.095	1.38930	4.736	1.667	3.76465	1.58512	1.64613	1.35527	0.99863	0.98768
5.000	16—0.065	1.00775	3.436	1.209	3.06839	1.22736	1.74494	1.10462	0.77324	1.04696
5.000	14—0.083	1.28212	4.371	1.539	3.87582	1.55033	1.73867	1.39530	0.97671	1.04320
5.000	13—0.095	1.46391	4.991	1.757	4.40417	1.76167	1.73450	1.58550	1.10985	1.04070
5.000	11—0.120	1.83972	6.272	2.208	5.47979	2.19192	1.72586	1.97272	1.38091	1.03552

Airplane Landing-Wheel Rims—Low-Pressure Type

(*Proposed S.A.E. Recommended Practice*)

The following proposed rims for low-pressure landing-wheel tires that were developed and approved with the other tire data submitted herewith are also submitted by the Division for adoption as S.A.E. Recommended Practice.



AIRPLANE WHEEL-RIMS FOR LOW-PRESSURE TIRES

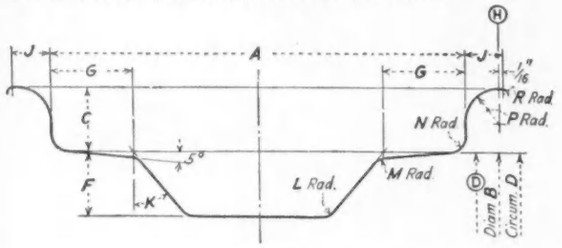
A Width between Flanges	*B* Minimum	*C* Flange Height	*D* Diameter	*F* Well Depth	*G* Ledge Width	*J* Minimum	*L* Radius	*L*1 Radius	*M* Radius	*N* Radius	*P* Radius	*R* Radius Minimum	*S* Radius	*T*	*U* Diameter	*V* Diameter
4¾	2 13/16	11/16	10.000	1¼	7/8	½	¼	¼	¼	7/32	3/8	1/16	1	19/32	7/8	11/16
5½	3½	11/16	10.000	1½	7/8	½	¼	¼	¼	7/32	3/8	1/16	1 1/8	19/32	7/8	11/16
6¼	3 11/16	11/16	10.000	1¾	7/8	½	¼	5/16	¼	7/32	3/8	1/16	1¼	5/8	7/8	11/16
7	3 15/16	3/4	12.000	1½	1 1/16	17/32	3/8	3/8	5/16	7/32	7/16	5/64	1 3/8	11/16	7/8	11/16
8¼	4¾	13/16	12.000	1½	1 1/16	9/16	3/8	3/8	5/16	7/32	7/16	5/64	1½	11/16	7/8	11/16
9½	5½	7/8	14.000	1 5/8	1 1/8	5/8	3/8	7/16	5/16	7/32	½	5/64	1¾	¾	1 1/8	25/32
11¼	6¾	1	16.000	1¾	1 5/16	11/16	½	5/8	5/16	¼	9/16	5/64	2	13/16	1 1/8	25/32

Tolerance on rim circumference, ±0.047 in.

Airplane Landing-Wheel Rims—High-Pressure Type

(Proposed Revision of S.A.E. Recommended Practice)

Mr. Cautley's Subdivision has likewise cooperated with the Tire & Rim Association in bringing this S.A.E. specification, p. 22 of the S.A.E. HANDBOOK, uptodate and the Division recommends that the present specification be revised by substituting the following maximum and minimum radii *L* at the bottom of the hole in the rims.



AIRPLANE-WHEEL RIMS

Rim Size, In.	Dimension *L* (Radius), In. Maximum	Minimum
3	1/8	..
4	1/8	..
5	1/4	1/8
6	3/8	3/16
8	3/8	3/16
10	1/2	3/16
12	9/16	3/16
14	5/8	3/8

Airplane Landing-Wheel Tires—Low-Pressure Type

(Proposed S.A.E. Recommended Practice)

Since the Society adopted the Recommended Practice for the High-Pressure Type of Landing-Wheel Tires, Mr. Cautley's Subdivision in cooperation with the Tire & Rim Association and the tire manufacturers has formulated the following proposed S.A.E. Recommended Practice for Low-Pressure Tires, their rim sizes and valves. These were approved by the Tire & Rim Association at its meeting last April and submitted to the Division at its meeting immediately thereafter. The Division now recommends their approval and adoption by the Society as S.A.E. Recommended Practice.

Airplane Tires—High-Pressure Type

(Proposed Revision of S.A.E. Recommended Practice)

During the past year a Subdivision under the chairmanship of John R. Cautley has been cooperating with the Tire and Rim Association on revision of the S.A.E. Recommended Practice for High-Pressure Airplane Tires. The proposed revisions were approved at the meeting of the Tire & Rim Association on April 16, were reported to the Aircraft Division at its meeting on April 17 and approved. The Division, therefore, recommends that the present S.A.E. Recommended Practice commencing on p. 20 of the 1931 edition of the S.A.E. HANDBOOK be revised accordingly.

HIGH-PRESSURE AIRPLANE-TIRE DIMENSIONS

	Wheel Size	Rim dimensions: Width bet. flanges	Rim dimensions: Ledge Diameter	Standard Tire Size	Oversize Tire for Extra Cushioning	Actual Tire Dimensions Plain Tread: Tire Section Width: Minimum	Tire Section Width: Maximum	Tired Over-all Height: Minimum	Tired Over-all Height: Maximum[d]
Tail-Wheel Sizes	10x3[c]	2 1/8	4	10x3[c]	12x4[c]	3.12 3.96	3.18 4.04	10.24 11.90	10.36 12.06
	14x3	2 1/8	8	14x3	16x4	3.12 3.96	3.18 4.04	14.24 15.90	14.36 16.06
	18x3	2 1/8	12	18x3	20x4	3.12 3.96	3.18 4.04	18.24 19.90	18.36 20.06
Landing-Wheel Sizes	24x4	2 1/2	16	24x4	26x5	3.96 4.83	4.04 4.93	23.90 25.56	24.06 25.76
	28x4	2 1/2	20	28x4	30x5	3.96 4.83	4.04 4.93	27.90 29.54	28.06 29.74
	30x5	3	20	30x5	32x6	5.00 5.83	5.10 5.95	29.56 31.31	29.76 31.53
	32x6	4	20	32x6	36x8	6.17 7.78	6.29 7.94	31.33 34.88	31.55 35.18
	36x8	5	20	36x8	40x10	8.12 9.74	8.28 9.95	34.91 37.99	35.21 38.35
	44x10	6	24	44x10		10.07	10.28	42.04	42.40
	54x12	7	30	54x12	58x14	12.00 14.22	12.26 14.50	51.63 55.26	52.07 55.78
	58x14	8	30	58x14		14.30	14.58	55.30	55.82

[c] Flat-base rims. All others are drop-center.

[d] The over-all height of non-skid tires may slightly exceed these dimensions.

LOW-PRESSURE TIRES FOR AIRPLANE LANDING-WHEELS

Tire and Wheel Size	Axle Dimensions: Stub Diameter	Axle Dimensions: Minimum Length of Stub	Axle Dimensions: Bolt Circle	Axle Dimensions: Bolt Holes	Axle Dimensions: No. of Bolts	Axle Dimensions: Diameter of Bolts	Rim Dimensions: Rim Width	Rim Dimensions: Flange Height	Tire Dimensions: Cross-Section: Minimum	Tire Dimensions: Cross-Section: Maximum	Tire Dimensions: Outside Diameter: Minimum	Tire Dimensions: Outside Diameter: Maximum	Loads and Inflation Pressures: Maximum Static Load	Loads and Inflation Pressures: Air Pressure	Loads and Inflation Pressures: Equivalent High Pressure Size	Valve [b]
6.50–10	1.5	3.0	4.00	12	6	0.25	4 3/4	11/16	6.50	6.63	21.70	21.94	1,000	20	28x4	90
7.50–10	1.5	3.0	4.00	12	6	0.25	5 1/2	11/16	7.50	7.65	23.50	23.77	1,250	20	None	90
8.50–10	2.0	4.0	4.00	12	6	0.375	6 1/4	11/16	8.50	8.67	25.30	25.62	1,600	20	30x5	90
9.50–12	2.0	4.0	4.75	12	6	0.375	7	3/4	9.50	9.69	29.10	29.44	2,200	20	32x6	90
11.00–12	2.5	5.0	4.75	12	12	0.375	8 1/4	13/16	11.00	11.22	31.80	32.20	3,000	23	None	90
12.50–14	2.5	5.0	5.75	12	12	0.375	9 1/2	7/8	12.50	12.75	36.00	36.44	4,000	25	36x8	91
15.00–16	3.0	6.0	8.00	12	6	0.5625	11 1/4	1	15.00	15.30	41.80	42.31	6,200	25	44x10	91

[b] Numbers refer to Tire & Rim Association standards.

HIGH-PRESSURE AIRPLANE-TIRE LOADS AND INFLATION-PRESSURES

Minimum Inflation-Pressure, Lb. per Sq. In.	Tail-Wheel Tires, In.				Landing-Wheel Tires, In.											
	10x3	14x3	18x3	12x4	16x4	20x4	24x4	28x4	26x5	30x5	32x6	36x8	40x10	44x10	54x12	58x14
	Maximum Load per Tire, Lb.															
30	225	275	300	325	400	450	510	600	810	950						
35	260	320	350	380	470	525	595	700	945	1,120	1,400	2,330				
40	295	365	400	435	540	600	680	800	1,080	1,280	1,600	2,670	3,390			
45	330	410	450	490	610	675	765	900	1,215	1,440	1,800	3,006	3,810	4,360	6,430	
50	365	455	500	545	680	750	850	1,000	1,350	1,600	2,000	3,330	4,230	4,850	7,150	
55	400	500	550	600	750	825					2,200	3,670	4,650	5,330	7,850	10,200
60												4,000	5,080	5,820	8,570	11,100
65													5,500	6,300	9,280	12,100
70															10,000	13,000

Underscoring denotes maximum recommended static loads.

HIGH-PRESSURE AIRPLANE TIRE AND WHEEL COMBINATIONS

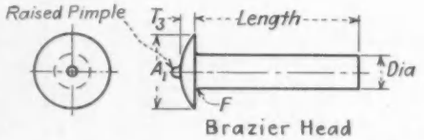
	Wheel Size	Standard Tire Size	Oversize Tire for Extra Cushioning	Recommended Maximum Static Load Lb.	Inflation Pressure, Lb.	Maximum Tire Deflection,* Per Cent	Static Load To Collapse Tire Completely at Foregoing Inflation Lb.	Minimum Wheel-Strength, Lb.	
								Radial	Side
Tail-Wheel Sizes	10x3	10x3	12x4	400	55	25.0	1,800	.....	.....
				400	37	25.0	2,300		
	14x3	14x3	16x4	500	55	25.0	2,000	3,000	.....
				500	37	25.0	2,600		
	18x3	18x3	20x4	550	55	25.0	2,200	5,000	2,000
				550	37	25.0	2,800		
Landing-Wheel Sizes	24x4	24x4	26x5	850	50	27.5	3,500	7,000	2,500
				850	32	27.5	3,600		
	28x4	28x4	30x5	1,000	50	27.5	3,700	8,500	3,000
				1,000	32	27.5	3,800		
	30x5	30x5	32x6	1,600	50	27.5	5,100	11,000	3,300
				1,600	38	27.5	6,200		
	32x6	32x6	36x8	2,200	55	27.5	8,000	13,500	4,050
				2,200	35	27.5	9,800		
	36x8	36x8	40x10	4,000	60	27.5	13,500	20,000	6,000
				4,000	47	27.5	16,500		
	44x10	44x10		6,300	65	27.5	20,800	33,000	9,900
	54x12	54x12	58x14	10,000	70	27.5	35,000	50,000	15,000
				10,000	55	27.5	39,000		
	58x14	58x14		13,000	70	27.5	50,000	65,000	.....

* Tire deflection is based on tire height above rim flange.

Brazier-Head Rivets

(Proposed Addition to S.A.E. Standard)

The Division recommends adoption of the following brazier-head rivets for inclusion in the S.A.E. Standard for Aluminum-Alloy Rivets, p. 62 of the 1931 edition of the S.A.E. HANDBOOK. This recommendation is the result of further study of rivet standardization that resulted in adoption of the Standard for Aluminum and Aluminum-Alloy Rivets at the Annual Meeting last January.



ALUMINUM-ALLOY RIVET DIMENSIONS

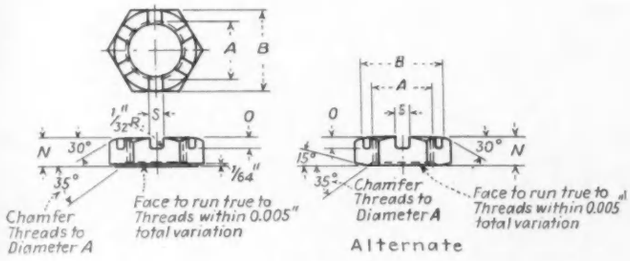
Body Diameter, In.	A_1	T_3
1/16 +0.003—0.001	5/32 ±0.008	1/32 ±0.005
3/32 +0.003—0.001	15/64 ±0.012	3/64 ±0.005
1/8 +0.0035—0.001	5/16 ±0.016	1/16 ±0.005
5/32 +0.004—0.001	25/64 ±0.020	5/64 ±0.005
3/16 +0.004—0.001	15/32 ±0.023	3/32 ±0.005
1/4 +0.004—0.001	5/8 ±0.031	1/8 ±0.006
5/16 +0.004—0.001	25/32 ±0.039	5/32 ±0.008
3/8 +0.004—0.001	15/16 ±0.047	3/16 ±0.009

F is a fillet with a maximum radius of 0.1 in.
Heads of all rivets to raised pimple for identification.
Rivet lengths to be the same as given in Table 3, p. 63, 1931 S.A.E. HANDBOOK. Length tolerance is ±0.010 in.

Slotted Shear-Nuts

(Proposed Addition to S.A.E. Standard)

The accompanying specification for this type of nuts was formulated by the Division and checked by the Screw-Threads Division and is now submitted to the Society with the recommendation that it be included in the present S.A.E. Standards for Plain and Castle Hexagon Nuts, pp. 66 and 67 of the 1931 edition of the S.A.E. HANDBOOK. The Division also recommends that the specifications for these three types of nuts be combined into one S.A.E. Standard for Aircraft Hexagon Nuts.



SLOTTED SHEAR-NUTS

Bolt Size A Threads per Inch[f]	B	N	S +0.010 −0.000	O
0.1900 (No. 10)—32	3/8	3/16	5/64	3/32
0.2500 (1/4)—28	7/16	3/16	5/64	3/32
0.3125 (5/16)—24	1/2	3/16	5/64	3/32
0.3750 (3/8)—24	9/16	7/32	1/8	7/64
0.4375 (7/16)—20	5/8	7/32	1/8	7/64
0.5000 (1/2)—20	3/4	1/4	1/8	7/64
0.5625 (9/16)—18	7/8	5/16	5/32	1/8
0.6250 (5/8)—18	1	5/16	5/32	1/8
0.7500 (3/4)—16	1 1/8	3/8	5/32	1/8
0.8750 (7/8)—14	1 5/16	7/16	5/32	1/8
1.0000 (1)—14	1 1/2	1/2	5/32	1/8

[f] Finished sizes include plating or protective coating.

All threads are American Standard (National Fine Pitch), with Class 3 tolerances.

Tolerances are ±0.010 in. except where otherwise indicated.

Aircraft-Engine Division

PERSONNEL

Arthur Nutt, *Chairman*	Wright Aeronautical Corp.
Robert Insley, *Vice-Chairman*	Continental Aircraft Engine Co.
C. S. Fliedner	Bureau of Aeronautics, Navy Department
E. D. Herrick	Lycoming Mfg. Co.
Ludwig A. Majneri	Warner Aircraft Corp.
Capt. E. R. Page, U. S. A.	Materiel Division, Air Corps
M. J. Steele	Packard Motor Car Co.
Andrew V. D. Willgoos	Pratt & Whitney Aircraft Co.

Propeller Blade-Ends

(Proposed Cancellation of S.A.E. Standard)

Propeller-Blade Clamp-Rings, Bolts and Nuts

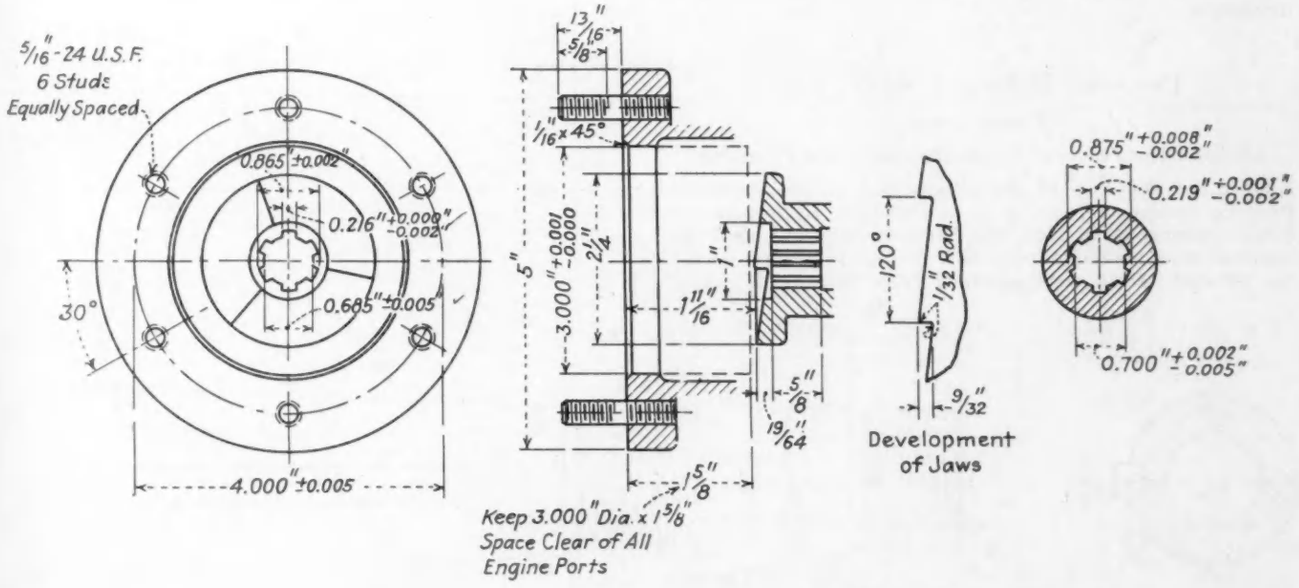
(Proposed Cancellation of S.A.E. Recommended Practice)

At the meeting of the Division last April the suggestion was made that inasmuch as the design incorporated in the present S.A.E. specifications commencing on p. 4 of the 1931 edition of the S.A.E. HANDBOOK are being rapidly superseded by refined designs in other types of mounting, and that it is unnecessary to supersede the present specifications by any other at present, the Division accordingly recommends that the present specifications be cancelled.

Engine-Starter Mountings—Small Type

(Proposed Revision of S.A.E. Standard)

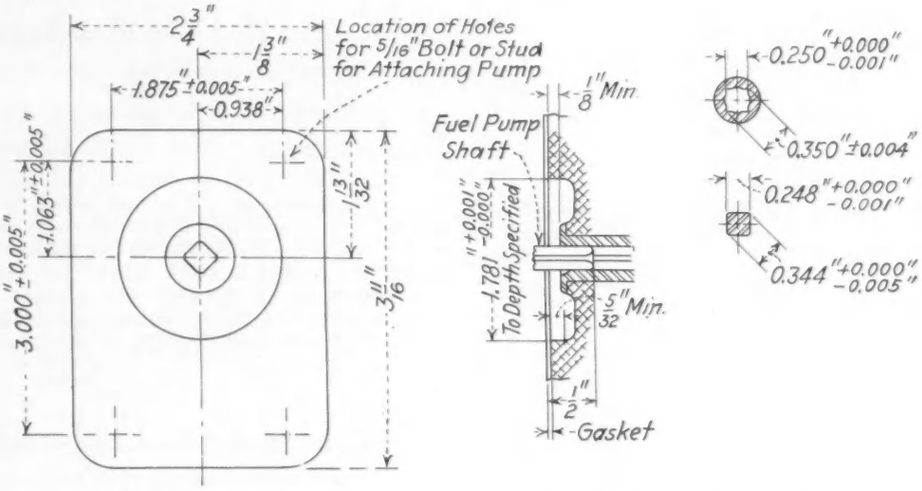
At the Aircraft-Engine Division meeting last April the proposal was made that the dimensions of the splined shaft for the small type of engine-starter, p. 9 of the 1931 edition of the S.A.E. HANDBOOK, be revised to conform to the shaft of the generator shown on p. 7 to have these two standards uniform. This proposal was approved by the Division inasmuch as it was indicated that this change has already been effected by the starter manufacturers. The Division accordingly recommends that the present S.A.E. Standard be revised in accordance with the accompanying illustration.



Fuel-Pump Mounting

(Proposed Revision of S.A.E. Standard)

Division Chairman Hardecker, at the meeting of the Division last April, pointed out that fuel pumps are mounted by either bolts or studs in the mounting pad shown on p. 12 of the 1931 edition of the S.A.E. HANDBOOK and that the present standard should be modified accordingly, rather than showing bolt holes. The Division accordingly recommends that this revision be made and that the end view show also the pilot and shaft end as shown in the accompanying illustration.



Piston Rings

(Proposed S.A.E. Standard)

For some time the Division has been considering the standardization of piston rings for aircraft engines but a careful study indicates that this is not considered feasible. The Division does, however, feel that the present S.A.E. Standard for Piston and Piston-Ring Oversizes and Ring Widths, shown on p. 83 of the 1931 edition of the S.A.E. HANDBOOK, is suitable for airplane engines and accordingly recommends that a note referring to the present specifications be included in the Aeronautic Section of the S.A.E. HANDBOOK.

Propeller Hubs and Shaft Ends

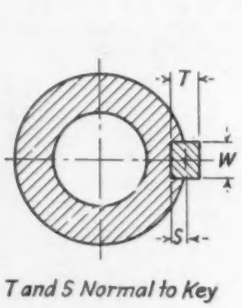
Taper Type

(Proposed Revision of S.A.E. Recommended Practice)

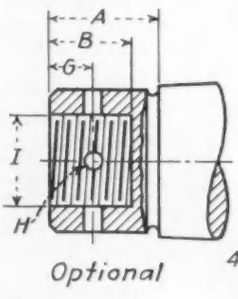
Since the adoption of the present S.A.E. Recommended Practice commencing on p. 1 of the 1931 edition of the S.A.E. HANDBOOK in 1928, the Division has considered the addition of a similar taper shaft end to be known as the No. 00 size. Data were obtained from the engine manufacturers building this small-size engine from which the accompanying recommendation was developed and is now recommended for inclusion in the present S.A.E. Recommended Practice. The Division also recommends that the key dimensions for the Nos. 1 and 2 shaft sizes be revised in accordance with the accompanying table to make them more consistent with current practice.

SHAFT ENDS WITH INTERNAL THREADS

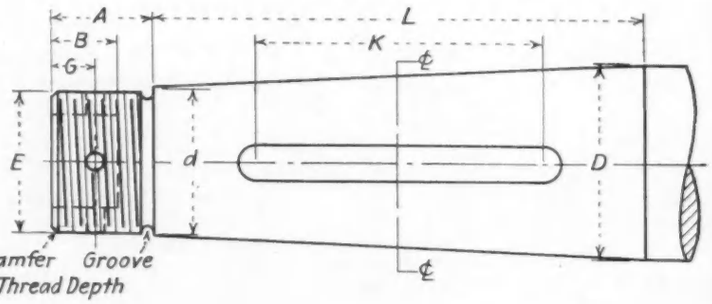
S.A.E. Shaft No.	Internal Thread (Optional)			Locking Holes		
	B	*I*	Pitch Diameter Minimum	*G*	*H*	*N*
00	None			3/16	5/32	1-Thru
0	5/8	7/8"-18	0.8390	1/4	7/32	4
1	7/8	15/16"-24	0.9104	15/32	13/64	5
2	1 1/16	1"-14	0.9536	.....	.....	.....



T and S Normal to Key



Optional



45° Chamfer Groove Full Thread Depth

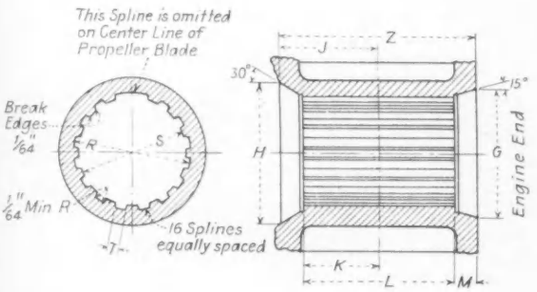
SHAFT ENDS WITH EXTERNAL THREADS

S. A. E. Shaft No.	TAPER				KEY				EXTERNAL THREAD		
	L	D	d	Taper[a]	K	W +0.0000 −0.0005	T +0.000 −0.007	S +0.010 −0.000	A[b]	E	Pitch Diameter Maximum
00	3	1.250	0.950	1″ in 10″	1 5/8	0.2495	0.250	0.154	1	3/4″-16	0.7094
0	3 5/8	1.875	1.512	1″ in 10″	2 1/4	0.3750	0.278	0.154	13/16	1 3/8″-18	1.3390
1	5 5/32	2.050	1.535	1″ in 10″	3	0.3750	0.278	0.154	1 1/16	1 1/2″-18	1.4640
2	7	2.362	1.662	1″ in 10″	5 1/16	0.4730	0.237	0.143	1 1/4	1 9/16″-12	1.5084

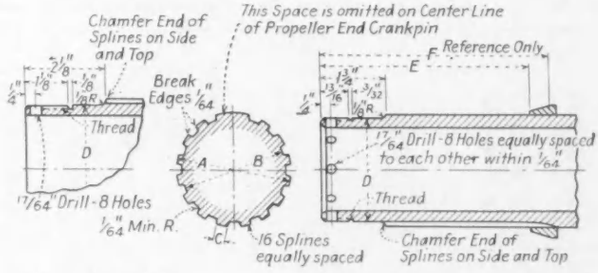
[a] The taper (included angle) should vary from absolute uniformity by being from 0.000 to 0.001 in. large at end.
[b] No. 00 shaft end is designed for use of standard S.A.E. 3/4-in. castle nut. All other sizes require special nuts.

Splined Type

The Division has been working for some time on the dimensions for a large No. 50 size shaft end as well as the refinement of the dimensions for the smaller sizes, including the propeller hubs, nuts and rings. This report was checked with the Army-Navy Standards and was approved at the meeting of the Aircraft-Engine Division held on April 18. The following revised specifications for these shaft ends are accordingly submitted for approval and adoption by the Society.



Shaft End for No. 50 on


Chamfer End of Splines on Side and Top
This Space is omitted on Center Line of Propeller End Crankpin
Break Edges 1/64"
Thread
17/64" Drill - 8 Holes
1/64" Min. R.
16 Splines equally spaced
E Reference Only
17/64" Drill - 8 Holes equally spaced to each other within 1/64"
Chamfer End of Splines on Side and Top

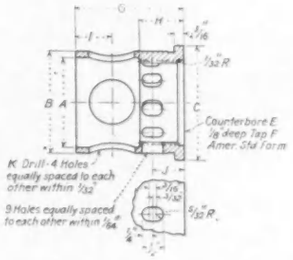
Shaft Ends for Nos. 10, 20, 30 and 40

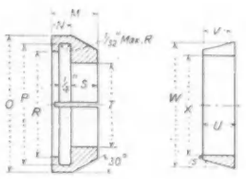
SPLINED TYPE SHAFT-END DIMENSIONS

Shaft No.	A +0.000 −0.002	B (Maximum)	C ±0.0008	Thread	D +0.000 −0.002	E ±0.030	F
10	2.000	1.781	0.1940	1 13/16-12 American Standard Form 1.631 +0.000 −0.002 Pitch Diameter	1.687	4.844	5 3/8
20	2.375	2.156	0.2310	2 1/16-12 American Standard Form 2.006 +0.000 −0.002 Pitch Diameter	2.062	5.594	6 1/8
30	2.625	2.406	0.2570	2 5/16-12 American Standard Form 2.256 +0.000 −0.002 Pitch Diameter	2.312	5.969	6 1/2
40	3.125	2.875	0.3040	2 13/16-12 American Standard Form 2.757 +0.000 −0.002 Pitch Diameter	2.812	5.594	6 1/8
50	3.804	3.554	0.3750	3 7/16-12 American Standard Form 3.381 +0.000 −0.002 Pitch Diameter	3.500	6.344	6 31/32

SPLINED-TYPE PROPELLER-HUB DIMENSIONS

Hub No.	*H* +0.005 −0.000	*G* +0.005 −0.000	*J*	*K*	*L*	*M*	*R* (Minimum)	*S* +0.005 −0.002	*T* ±0.001	*Z*
10	2.750	2.500	2 7/32	1 5/8	3 1/4	5/8	2.006	1.789	0.196	4 15/32
20	3.125	2.875	2 5/8	2	4	5/8	2.381	2.164	0.233	5 1/4
30	3.187	3.187	2 25/32	2 3/16	4 3/8	5/8	2.631	2.414	0.259	5 19/32
40	3.875	3.625	2 5/8	2	4	5/8	3.131	2.881	0.306	5 1/4
50	4.562	4.625	2 13/16		4 11/32	13/16	3.810	3.562	0.377	5 51/64

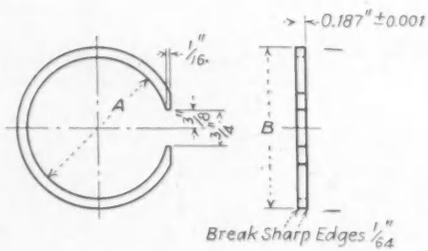

1/16"
1/32" R
Counterbore E 1/8 deep Tap F Amer. Std Form
K Drill 4 Holes equally spaced to each other within 1/32"
9 Holes equally spaced to each other within 1/64"
5/32" R.



PROPELLER CONE AND NUT DIMENSIONS

Shaft No.	*A*	*B*	*C*	*E*	*F*	*G*	*H*	*I*	*J*	*K*
10	1 13/16	2 1/16	2 5/16	1 45/64	1 11/16–12	2 1/8	7/8	1 1/16	21/32	57/64
20	2 3/16	2 7/16	2 11/16	2 5/64	2 1/16–12	2 1/8	7/8	1 1/16	5/8	57/64
30	2 3/8	2 5/8	2 15/16	2 21/64	2 5/16–12	2 1/8	7/8	1 1/16	21/32	57/64
40	2 15/16	3 3/16	3 7/16	2 7/8	2 13/16–12	2 1/8	7/8	23/32	5/8	57/64
50	3 15/32	3 3/4	4 3/16	3 9/16	3 7/16–12	2 7/8	1 9/32	27/32	1	1 1/32

Shaft No.	*M*	*N*	*O*	*P*	*R*	*S*	*T* ±0.0005	*U*	*V*	*W*	*X* ±0.0005
10	29/32	13/32	2 3/4	2 7/16	2 1/8	17/32	1.6875	3/4	17/32	2.500	2.001
20	29/32	13/32	3 1/8	2 13/16	2 1/2	17/32	2.0625	3/4	17/32	2.875	2.376
30	29/32	25/64	3 1/4	3	2 11/16	1/2	2.3125	3/4	17/32	3.187	2.626
40	29/32	13/32	3 3/8	3 9/16	3 1/4	17/32	2.8125	3/4	17/32	3.625	3.126
50	1	7/16	4 9/16	4 1/4	3 15/16	9/16	3.5005	7/8	5/8	4.625	3.813



SNAP RING DIMENSIONS

Shaft No.	*A*	*B*
10	2 5/8	3
20	3	3 3/8
30	3 1/32	3 13/32
40	3 3/4	4 1/8
50	4 3/8	4 3/4

Ball and Roller Bearings Division

PERSONNEL

G. R. Bott, *Chairman*	Norma-Hoffmann Bearings Corp.
E. R. Carter, Jr., *Vice-Chairman*	The Fafnir Bearing Co.
H. E. Brunner	S.K.F. Industries, Inc.
F. H. Buhlman	Rollway Bearing Co., Inc.
D. F. Chambers	Bearings Co. of America
L. A. Cummings	Marlin-Rockwell Corp.
T. C. Delaval-Crow	New Departure Mfg. Co.
H. R. Gibbons	Hyatt Bearings Division of the General Motors Corp.
K. L. Herrmann	Bantam Ball Bearing Co.
H. N. Parsons	Strom Bearings Co.
Ernest Wooler	Timken Roller Bearing Co.

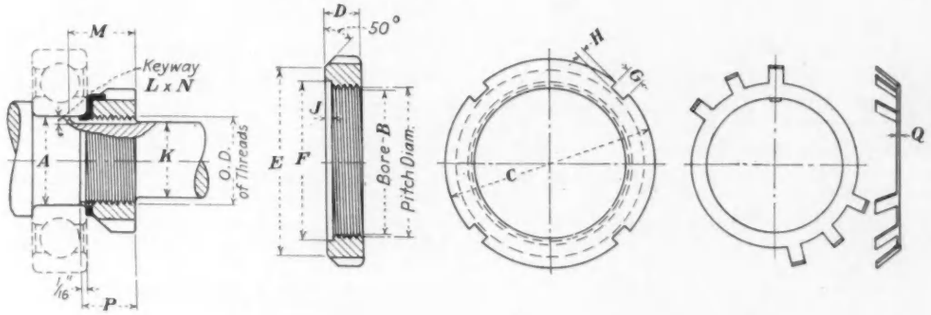
Ball-Bearing Lock-Nuts and Washers

(Proposed Extension of S.A.E. Recommended Practice)

At the time the Division submitted its original report to the Society last January, the lock-nut dimensions for sizes Nos. 0 to 14 inclusive were approved but the sizes larger than No. 14 were referred back to the Division by the Council because of a difference in practice between the use of 11 and 12 pitch threads for the larger size nuts. As the result of further consideration of these thread pitches, the

Division at its meeting on April 28 at which the makers of these lock nuts and washers were represented, approved the recommendation that the Society adopt the sizes Nos. 15 to 40 inclusive, omitting all odd-numbered sizes from 23 to 39 inclusive. It was also recommended that 12 pitch threads be adopted for sizes Nos. 15 to 30 inclusive and 8 pitch threads for sizes Nos. 32 to 40 inclusive with a footnote following the table as shown in the accompanying report.

The Division, in submitting its report originally, did so with the understanding that the limit dimensions of the threads on the shafts and in the nuts would be revised in accordance with class 3 fits for screw threads as established by the American Standard. This part of the report was referred to the Screw-Threads Division of the Standards Committee which is now working on the revision of this part of the report. In the meantime, however, the manufacturers' limits on the threads are published with the report as shown. The Division accordingly recommends adoption of the following report for extension of the present S.A.E. Recommended Practice, pp. 304 to 306 inclusive of the 1931 edition of the S.A.E. HANDBOOK.



BALL-BEARING LOCK-NUTS AND WASHERS

Lock-Nut No.	Bearing Bore	Nut								Shaft				Washer Thickness Q	Threads, American Standard Form				
		Bore B	O. D. C	Width D	O. D. of Face E	Relief Diameter F	Slot Width G	Slot Depth H	Relief Depth J	Ext. Shaft K Max.	Keyway Depth L	Keyway Width N	Thread Length P		Pitch[1]	Pitch Diameters			
																Shaft[2]		Nut	
																Maximum	Minimum	Maximum	Minimum
15	2.9528	2.8300	3 7/8	13/32	3 5/16	3	3/8	5/32	3/32	2 25/32	1/8	5/16	23/32	0.072	12	2.879	2.875	2.883	2.879
16	3.1496	3.0340	4 5/32	13/32	3 27/32	3 5/16	3/8	5/16	3/32	3	1/8	3/8	23/32	0.072	12	3.083	3.079	3.087	3.083
17	3.3465	3.2370	4 13/32	7/8	4 1/32	3 3/8	3/8	5/16	3/32	3 5/16	1/8	3/8	3/4	0.072	12	3.286	3.282	3.290	3.286
18	3.5433	3.4240	4 31/32	1 1/16	4 1/32	3 13/32	3/8	5/16	3/32	3 3/8	1/8	3/8	27/32	0.094	12	3.473	3.469	3.481	3.473
19	3.7402	3.6270	4 15/16	1 1/16	4 1/32	4 1/16	3 13/32	5/16	3/32	3 9/16	1/8	3/8	7/8	0.094	12	3.676	3.672	3.680	3.676
20	3.9370	3.8150	5 1/16	3/4	4 13/16	4	3/8	5/16	3/32	3 25/32	1/8	3/8	29/32	0.094	12	3.864	3.860	3.868	3.864
21	4.1339	4.0180	5 1/16	3/4	5	4 1/32	1/2	1/32	3/32	3 15/16	1/8	3/8	29/32	0.094	12	4.068	4.064	4.072	4.068
22	4.3307	4.2210	5 23/32	29/32	5 7/32	4 13/32	1/2	1/32	1/8	4 5/16	5/32	3/8	31/32	0.125	12	4.271	4.267	4.275	4.271
24	4.7244	4.6120	6 1/8	13/16	5 11/16	4 13/16	1/2	1/32	1/8	4 5/16	5/32	3/8	1	0.125	12	4.662	4.658	4.666	4.662
26	5.1181	5.0020	6 3/4	29/32	6 3/16	5 7/32	5/8	1/4	1/8	4 15/16	5/32	1/2	1 1/32	0.125	12	5.052	5.048	5.056	5.052
28	5.5118	6.3930	7 3/32	13/16	6 17/32	5 15/32	5/8	1/4	1/8	5 5/16	5/32	1/2	1 1/8	0.125	12	5.443	5.439	5.447	5.443
30	5.9055	5.7840	7 11/16	1	7 1/16	6	5/8	5/32	1/8	5 23/32	3/16	1/2	1 7/32	0.156	12	5.834	5.830	5.838	5.834
32	6.2992	6.1900	8 1/16	1 1/32	7 1/16	6 3/16	5/8	5/32	1/8	6 1/8	3/16	1/2	1 1/4	0.156	8	6.203	6.198	6.208	6.203
34	6.6929	6.5800	8 21/32	1 1/16	8 1/32	6 25/32	5/8	5/32	1/8	6 1/2	3/16	1/2	1 9/32	0.156	8	6.578	6.573	6.583	6.578
36	7.0866	6.9710	9 1/16	1 1/8	8 3/32	7 1/32	3/4	5/16	1/8	6 29/32	3/16	1/2	1 11/32	0.156	8	6.985	6.980	6.990	6.985
38	7.4803	7.3620	9 13/32	1 1/8	8 29/32	7 1/16	3/4	5/16	1/8	7 5/16	3/16	1/2	1 11/32	0.156	8	7.391	7.386	7.396	7.391
40	7.8740	7.7520	9 31/32	1 1/16	9 1/32	8	3/4	5/16	1/8	7 11/16	3/16	1/2	1 11/32	0.156	8	7.766	7.761	7.771	7.766

[1] Lock nuts in sizes No. 15 and larger may be obtained with 11 threads per inch for servicing requirements during the transition to the 12 and 8 pitch threads in standard practice.

[2] The dimensions given are the manufacturers' present limits. These are being reviewed by the Screw-Threads Division of the Standards Committee for such revisions as may be required to have them conform to the American Standard Fine Pitches, Class 3 fit.

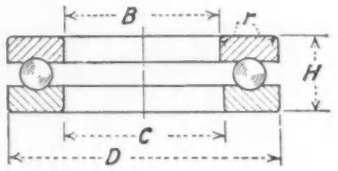
Metric Thrust Ball Bearings

(Proposed Revision of S.A.E. Standard)

The original S.A.E. Standard for Thrust Ball Bearings was adopted in 1917 and supplemented in August, 1918. Some time after the Sectional Committee on the Standardization of Ball Bearings was organized in 1920, a proposal was received from abroad that international standards for metric thrust ball bearings be developed. The Sectional Committee that is sponsored by the Society and the American Society of Mechanical Engineers under the procedure of the American Standards Association referred this subject to the Ball and Roller Bearings Division of the Society, which has compared the proposals received from abroad with American practice and has given careful study to the possibility of setting up uniform international standards. This study has shown that the manufacture and use of metric thrust ball bearings in America has not followed closely the early standards published by the S.A.E. and that in general the use of this type of bearings in America is very limited, whereas their use is much more general abroad. This has led to the decision by the Division that under the conditions it would be uneconomic and unwise for the American bearing manufacturers to attempt to change their practice to meet that abroad for the sake of having an international standard. The Division does feel, however, that an international standard among those countries desiring it is entirely feasible. Accordingly the Division has proceeded on the basis of revising the S.A.E. Standard to meet existing American conditions so far as metric thrust ball bearings are concerned and to eliminate the relatively few variations among American manufacturers that now exist.

The Subdivision, comprising E. R. Carter, Jr., *chairman;* D. F. Chambers, John English, H. N. Parsons and R. M. Riblet, has prepared the accompanying report which was approved by the Ball and Roller Bearings Division at its meeting in New York City on April 28 and is now submitted

by the Division for adoption by the Society to supersede all of the present thrust ball bearing tables, pp. 318 to 333 inclusive, of the 1931 edition of the S.A.E. HANDBOOK. The tolerances in the accompanying recommendation are larger than those for annular ball bearings for manufacturing reasons and because they are not so important for the mounting of the bearings. The present S.A.E. Standard for the Steering Knuckle Type of Thrust Ball Bearing that is included in these tables is now being studied by the Subdivision for revision and will be reported to the Standards Committee and Society at a later date.



SINGLE-DIRECTION, FLAT-FACE TYPE, LIGHT SERIES

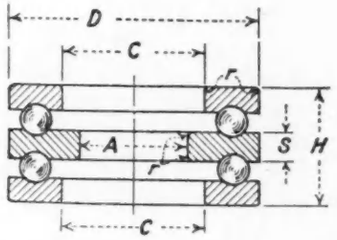
Bearing No.	Inside Diameter B		Diameter C		Outside Diameter D		Height H		Chamfer or Radius r Minimum	
	Mm.	In.	Mm.	In.	Mm.	In.	Mm.	In.	Mm.	In.
TPL10	10	0.3937	10.5	0.413	26	1.0236	12	0.4724	1	0.04
TPL12	12	0.4724	12.5	0.492	28	1.1024	12	0.4724	1	0.04
TPL15	15	0.5906	15.5	0.610	31	1.2205	12	0.4724	1	0.04
TPL18	18	0.7087	18.5	0.728	35	1.3780	12	0.4724	1	0.04
TPL20	20	0.7874	20.5	0.807	37	1.4567	12	0.4724	1	0.04
TPL25	25	0.9843	25.5	1.004	45	1.7717	14	0.5512	1	0.04
TPL30	30	1.1811	30.5	1.201	50	1.9685	14	0.5512	1	0.04
TPL35	35	1.3780	35.5	1.398	55	2.1654	16	0.6299	1	0.04
TPL40	40	1.5748	40.5	1.594	60	2.3622	16	0.6299	1	0.04
TPL45	45	1.7717	45.5	1.791	68	2.6772	16	0.6299	1	0.04
TPL50	50	1.9685	50.5	1.988	74	2.9134	18	0.7087	1	0.04
TPL55	55	2.1654	55.5	2.185	78	3.0709	18	0.7087	1	0.04
TPL60	60	2.3622	60.5	2.382	82	3.2284	18	0.7087	1	0.04
TPL65	65	2.5591	65.5	2.579	90	3.5433	20	0.7874	1	0.04
TPL70	70	2.7559	70.5	2.776	95	3.7402	20	0.7874	1	0.04
TPL75	75	2.9528	75.5	2.972	100	3.9370	20	0.7874	1	0.04
TPL80	80	3.1496	80.5	3.169	110	4.3307	22	0.8661	1	0.04
TPL85	85	3.3465	85.5	3.366	115	4.5276	22	0.8661	1	0.04
TPL90	90	3.5433	90.5	3.563	120	4.7244	22	0.8661	1	0.04
TPL95	95	3.7402	95.5	3.760	130	5.1181	25	0.9843	1	0.04
TPL100	100	3.9370	100.5	3.957	135	5.3150	25	0.9843	1	0.04
TPL105	105	4.1339	105.5	4.154	140	5.5118	25	0.9843	1	0.04
TPL110	110	4.3307	110.5	4.350	145	5.7087	25	0.9843	1	0.04
TPL115	115	4.5276	115.5	4.547	150	5.9055	25	0.9843	1	0.04
TPL120	120	4.7244	120.5	4.744	160	6.2992	27	1.0630	1	0.04
TPL125	125	4.9213	125.5	4.941	165	6.4961	27	1.0630	1	0.04

SINGLE-DIRECTION, FLAT-FACE TYPE, MEDIUM SERIES

Bearing No.	Inside Diameter B		Diameter C		Outside Diameter D		Height H		Chamfer or Radius r Minimum	
	Mm.	In.	Mm.	In.	Mm.	In.	Mm.	In.	Mm.	In.
TPM10	10	0.3937	11	0.433	30	1.1811	12	0.4724	1.0	0.04
TPM12	12	0.4724	13	0.512	32	1.2598	12	0.4724	1.0	0.04
TPM15	15	0.5906	16	0.630	35	1.3780	14	0.5512	1.0	0.04
TPM17	17	0.6693	18	0.709	38	1.4961	14	0.5512	1.0	0.04
TPM20	20	0.7874	21	0.827	40	1.5748	14	0.5512	1.0	0.04
TPM25	25	0.9843	26	1.024	48	1.8898	15	0.5906	1.0	0.04
TPM30	30	1.1811	31	1.221	53	2.0866	15	0.5906	1.0	0.04
TPM35	35	1.3780	36	1.417	62	2.4409	18	0.7087	1.5	0.06
TPM40	40	1.5748	41	1.614	64	2.5197	18	0.7087	1.5	0.06
TPM45	45	1.7717	46	1.811	73	2.8740	20	0.7874	1.5	0.06
TPM50	50	1.9685	51	2.008	78	3.0709	20	0.7874	1.5	0.06
TPM55	55	2.1654	56	2.205	88	3.4646	24	0.9449	1.5	0.06
TPM60	60	2.3622	61	2.402	90	3.5433	24	0.9449	1.5	0.06
TPM65	65	2.5591	66	2.598	100	3.9370	27	1.0630	2.0	0.08
TPM70	70	2.7559	71	2.795	103	4.0551	27	1.0630	2.0	0.08
TPM75	75	2.9528	76	2.992	110	4.3307	27	1.0630	2.0	0.08
TPM80	80	3.1496	81	3.189	115	4.5276	31	1.2205	2.0	0.08
TPM85	85	3.3465	86	3.386	125	4.9213	34	1.3386	2.0	0.08
TPM90	90	3.5433	91	3.583	135	5.3150	36	1.4173	2.5	0.10
TPM95	95	3.7402	96	3.780	140	5.5118	38	1.4961	2.5	0.10
TPM100	100	3.9370	101	3.976	150	5.9055	38	1.4961	2.5	0.10
TPM105	105	4.1339	106	4.173	155	6.1024	40	1.5748	2.5	0.10
TPM110	110	4.3307	111	4.370	160	6.2992	40	1.5748	2.5	0.10
TPM115	115	4.5276	116	4.567	165	6.4961	43	1.6929	3.0	0.12
TPM125	125	4.9213	126	4.961	180	7.0866	46.5	1.8307	3.0	0.12
TPM140	140	5.5118	141	5.551	200	7.8740	52	2.0472	3.0	0.12

SINGLE-DIRECTION, FLAT-FACE TYPE, HEAVY SERIES

Bearing No.	Inside Diameter B		Diameter C		Outside Diameter D		Height H		Chamfer or Radius r Minimum	
	Mm.	In.	Mm.	In.	Mm.	In.	Mm.	In.	Mm.	In.
TPH25	25	0.9843	26	1.024	52	2.0472	16	0.6299	1.0	0.04
TPH30	30	1.1811	31	1.221	60	2.3622	19	0.7480	1.0	0.04
TPH35	35	1.3780	36	1.417	68	2.6772	22	0.8661	1.5	0.06
TPH40	40	1.5748	41	1.614	76	2.9921	25	0.9843	1.5	0.06
TPH45	45	1.7717	46	1.811	85	3.3465	28	1.1024	1.5	0.06
TPH50	50	1.9685	51	2.008	92	3.6220	31	1.2205	1.5	0.06
TPH55	55	2.1654	56	2.205	100	3.9370	33	1.2992	1.5	0.06
TPH60	60	2.3622	61	2.402	106	4.1732	35	1.3780	1.5	0.06
TPH65	65	2.5591	66	2.598	112	4.4094	36	1.4173	2.0	0.08
TPH70	70	2.7559	71	2.795	120	4.7244	38	1.4961	2.0	0.08
TPH75	75	2.9528	76	2.992	128	5.0394	41	1.6142	2.0	0.08
TPH80	80	3.1496	81	3.189	136	5.3543	44	1.7323	2.0	0.08
TPH85	85	3.3465	86	3.386	145	5.7087	47	1.8504	2.0	0.08
TPH90	90	3.5433	91	3.583	155	6.1024	50	1.9685	2.5	0.10
TPH95	95	3.7402	96	3.780	165	6.4961	54	2.1260	2.5	0.10
TPH100	100	3.9370	101	3.976	172	6.7716	57	2.2441	2.5	0.10
TPH105	105	4.1339	106	4.173	180	7.0866	60	2.3622	2.5	0.10
TPH110	110	4.3307	111	4.370	190	7.4803	63	2.4803	2.5	0.10



DOUBLE-DIRECTION, FLAT-FACE TYPE, LIGHT SERIES

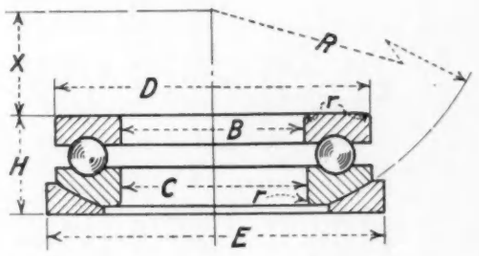
Bearing No.	Inside Diameter *A*		Diameter *C*		Outside Diameter *D*		Height *H*		Thickness of Central Washer *S*		Chamfer or Radius *r* Minimum	
	Mm.	In.	Mm.	In.	Mm.	In.	Mm.	In.	Mm.	In.	Mm.	In.
DTPL10	10	0.3937	15.5	0.610	31	1.2205	22	0.8861	6.0	0.2362	1	0.04
DTPL12	12	0.4724	18.5	0.728	35	1.3780	22	0.8861	6.0	0.2362	1	0.04
DTPL15	15	0.5906	20.5	0.807	37	1.4567	22	0.8861	6.0	0.2362	1	0.04
DTPL20	20	0.7874	25.5	1.004	45	1.7717	26	1.0236	7.0	0.2756	1	0.04
DTPL25	25	0.9843	30.5	1.201	50	1.9685	26	1.0236	7.0	0.2756	1	0.04
DTPL30	30	1.1811	40.5	1.594	60	2.3622	29	1.1417	7.5	0.2953	1	0.04
DTPL35	35	1.3780	45.5	1.791	68	2.6772	29	1.1417	7.5	0.2953	1	0.04
DTPL40	40	1.5748	50.5	1.988	74	2.9134	32	1.2598	8.0	0.3150	1	0.04
DTPL45	45	1.7717	55.5	2.185	78	3.0709	32	1.2598	8.0	0.3150	1	0.04
DTPL50	50	1.9685	60.5	2.382	82	3.2284	32	1.2598	8.0	0.3150	1	0.04
DTPL55	55	2.1654	65.5	2.579	90	3.5433	36	1.4173	9.0	0.3543	1	0.04
DTPL60	60	2.3622	70.5	2.776	95	3.7402	36	1.4173	9.0	0.3543	1	0.04
DTPL65	65	2.5591	75.5	2.972	100	3.9370	36	1.4173	9.0	0.3543	1	0.04
DTPL70	70	2.7559	80.5	3.169	110	4.3307	40	1.5748	10.5	0.4134	1	0.04
DTPL75	75	2.9528	85.5	3.366	115	4.5276	40	1.5748	10.5	0.4134	1	0.04
DTPL80	80	3.1496	90.5	3.563	120	4.7244	40	1.5748	10.5	0.4134	1	0.04
DTPL85	85	3.3465	95.5	3.760	130	5.1181	45	1.7717	11.0	0.4331	1	0.04
DTPL90	90	3.5433	100.5	3.957	135	5.3150	45	1.7717	11.0	0.4331	1	0.04
DTPL95	95	3.7402	105.5	4.154	140	5.5118	45	1.7717	11.0	0.4331	1	0.04
DTPL100	100	3.9370	110.5	4.350	145	5.7087	45	1.7717	11.0	0.4331	1	0.04

DOUBLE-DIRECTION, FLAT-FACE TYPE, MEDIUM SERIES

Bearing No.	Inside Diameter *A*		Diameter *C*		Outside Diameter *D*		Height *H*		Thickness of Central Washer *S*		Chamfer or Radius *r* Minimum	
	Mm.	In.	Mm.	In.	Mm.	In.	Mm.	In.	Mm.	In.	Mm.	In.
DTPM10	10	0.3937	16	0.630	35	1.3780	26	1.0236	7.0	0.2756	1.0	p.04
DTPM15	15	0.5906	26	1.024	48	1.8898	26	1.0236	7.0	0.2756	1.0	0.04
DTPM20	20	0.7874	31	1.221	53	2.0866	28	1.1024	7.0	0.2756	1.0	0.04
DTPM25	25	0.9843	36	1.417	62	2.4409	28	1.1024	7.0	0.2756	1.0	0.04
DTPM30	30	1.1811	41	1.614	64	2.5197	32	1.2598	7.5	0.2953	1.0	0.04
DTPM35	35	1.3780	46	1.811	73	2.8740	36	1.4173	8.0	0.3150	1.5	0.06
DTPM40	40	1.5748	51	2.008	78	3.0709	36	1.4173	8.0	0.3150	1.5	0.06
DTPM45	45	1.7717	56	2.205	88	3.4646	42	1.6535	9.0	0.3543	1.5	0.06
DTPM50	50	1.9685	61	2.401	90	3.5433	42	1.6535	9.0	0.3543	1.5	0.06
DTPM55	55	2.1654	66	2.598	100	3.9370	48	1.8898	11.0	0.4331	1.5	0.06
DTPM60	60	2.3622	71	2.795	103	4.0551	48	1.8898	11.0	0.4331	1.5	0.06
DTPM65	65	2.5591	76	2.992	110	4.3307	52	2.0472	15.0	0.5906	2.0	0.08
DTPM70	70	2.7559	81	3.189	115	4.5276	56	2.2047	15.0	0.5906	2.0	0.08
DTPM75	75	2.9528	86	3.386	125	4.9213	62	2.4409	15.0	0.5906	2.0	0.08
DTPM80	80	3.1496	91	3.583	135	5.3150	64	2.5197	15.0	0.5906	2.0	0.08
DTPM85	85	3.3465	96	3.780	140	5.5118	68	2.6772	16.0	0.6299	2.0	0.08
DTPM90	90	3.5433	101	3.976	150	5.9055	68	2.6772	16.0	0.6299	2.5	0.10
DTPM95	95	3.7402	106	4.173	155	6.1024	72	2.8346	17.0	0.6693	2.5	0.10
DTPM100	100	3.9370	111	4.370	160	6.2992	72	2.8346	17.0	0.6693	2.5	0.10
DTPM105	105	4.1339	116	4.567	165	6.4961	78	3.0709	18.0	0.7087	2.5	0.10
DTPM110	110	4.3307	126	4.961	180	7.0866	82	3.2283	18.0	0.7087	2.5	0.10

DOUBLE-DIRECTION, FLAT-FACE TYPE, HEAVY SERIES

Bearing No.	Inside Diameter *A*		Diameter *C*		Outside Diameter *D*		Height *H*		Thickness of Central Washer *S*		Chamfer or Radius *r* Minimum	
	Mm.	In.	Mm.	In.	Mm.	In.	Mm.	In.	Mm.	In.	Mm.	In.
DTPH15	15	0.5906	26	1.024	52	2.0472	29	1.1417	6	0.2362	1.0	0.04
DTPH20	20	0.7874	31	1.221	60	2.3622	35	1.3780	8	0.3150	1.0	0.04
DTPH25	25	0.9843	36	1.417	68	2.6772	40	1.5748	9	0.3543	1.0	0.04
DTPH30	30	1.1811	41	1.614	76	2.9921	46	1.8110	10	0.3937	1.0	0.04
DTPH35	35	1.3780	46	1.811	85	3.3465	52	2.0472	12	0.4724	1.5	0.06
DTPH40	40	1.5748	51	2.008	92	3.6220	57	2.2441	13	0.5118	1.5	0.06
DTPH45	45	1.7717	61	2.401	106	4.1732	65	2.5591	15	0.5906	1.5	0.06
DTPH50	50	1.9685	66	2.598	112	4.4094	67	2.6378	16	0.6299	1.5	0.06
DTPH55	55	2.1654	71	2.795	120	4.7244	71	2.7953	17	0.6693	1.5	0.06
DTPH60	60	2.3622	76	2.992	128	5.0394	76	2.9921	18	0.7087	1.5	0.06
DTPH65	65	2.5591	81	3.189	136	5.3543	81	3.1890	19	0.7480	2.0	0.08
DTPH70	70	2.7559	86	3.386	145	5.7087	87	3.4252	20	0.7874	2.0	0.08
DTPH75	75	2.9528	91	3.583	155	6.1024	92	3.6220	21	0.8268	2.0	0.08
DTPH80	80	3.1496	96	3.780	165	6.4961	98	3.8583	22	0.8661	2.0	0.08
DTPH85	85	3.3465	106	4.173	180	7.0866	109	4.2913	24	0.9449	2.0	0.08
DTPH90	90	3.5433	111	4.370	190	7.4803	115	4.5276	25	0.9843	2.5	0.10
DTPH95	95	3.7402	116	4.567	200	7.8740	120	4.7244	26	1.0236	2.5	0.10
DTPH100	100	3.9370	121	4.764	210	8.2677	125	4.9213	27	1.0630	2.5	0.10
DTPH110	110	4.3307	131	5.158	220	8.6614	131	5.1575	32	1.2598	2.5	0.10



SINGLE-DIRECTION, SELF-ALIGNING TYPE, LIGHT SERIES

Bearing No.	Inside Diameter *B*		Diameter *C*		Outside Diameter *D*		Diameter *E*		Height *H*		Radius *R*		*X*		Chamfer or Radius *r* Minimum	
	Mm.	In.	Mm.	In.	Mm.	In.	Mm.	In.	Mm.	In.	Mm.	In.	Mm.	In.	Mm.	In.
TSL10	10	0.3937	10.5	0.413	26	1.0236	30	1.1811	13.5	0.5315	22	0.8661	7.70	0.303	1	0.04
TSL12	12	0.4724	12.5	0.492	28	1.1024	32	1.2598	14.5	0.5709	25	0.9843	10.67	0.420	1	0.04
TSL15	15	0.5906	15.5	0.610	31	1.2205	35	1.3780	14.5	0.5709	25	0.9843	9.05	0.357	1	0.04
TSL18	18	0.7087	18.5	0.728	35	1.3780	37	1.4567	14.5	0.5709	30	1.1811	14.32	0.564	1	0.04
TSL20	20	0.7874	20.5	0.807	37	1.4567	40	1.5748	15.0	0.5906	30	1.1811	13.07	0.515	1	0.04
TSL25	25	0.9843	25.5	1.004	45	1.7717	48	1.8898	17.0	0.6693	40	1.5748	20.73	0.816	1	0.04
TSL30	30	1.1811	30.5	1.201	50	1.9685	53	2.0866	17.0	0.6693	45	1.7717	25.08	0.987	1	0.04
TSL35	35	1.3780	35.5	1.398	55	2.1654	60	2.3622	19.0	0.7480	45	1.7717	21.98	0.865	1	0.04
TSL40	40	1.5748	40.5	1.594	60	2.3622	65	2.5591	19.0	0.7480	55	2.1654	32.11	1.264	1	0.04
TSL45	45	1.7717	45.5	1.791	68	2.6772	72	2.8346	19.0	0.7480	60	2.3622	35.53	1.399	1	0.04
TSL50	50	1.9685	50.5	1.988	74	2.9134	78	3.0709	21.0	0.8268	60	2.3622	31.74	1.250	1	0.04
TSL55	55	2.1654	55.5	2.185	78	3.0709	82	3.2283	21.5	0.8465	65	2.5591	36.51	1.437	1	0.04
TSL60	60	2.3622	60.5	2.382	82	3.2284	86	3.3858	21.5	0.8465	70	2.7559	41.32	1.627	1	0.04
TSL65	65	2.5591	65.5	2.579	90	3.5433	95	3.7402	24.5	0.9646	75	2.9528	42.36	1.668	1	0.04
TSL70	70	2.7559	70.5	2.776	95	3.7402	100	3.9370	24.5	0.9646	80	3.1496	46.69	1.888	1	0.04
TSL75	75	2.9528	75.5	2.972	100	3.9370	105	4.1339	25.0	0.9843	85	3.3465	51.03	2.009	1	0.04
TSL80	80	3.1496	80.5	3.169	110	4.3307	115	4.5276	26.0	1.0236	100	3.9370	64.52	2.543	1	0.04
TSL85	85	3.3465	85.5	3.366	115	4.5276	120	4.7244	27.0	1.0630	100	3.9370	62.60	2.465	1	0.04
TSL90	90	3.5433	90.5	3.563	120	4.7244	125	4.9213	27.0	1.0630	105	4.1339	66.93	2.635	1	0.04
TSL95	95	3.7402	95.5	3.760	130	5.1181	135	5.3150	30.0	1.1811	110	4.3307	67.68	2.665	1	0.04
TSL100	100	3.9370	100.5	3.957	135	5.3150	140	5.5118	30.0	1.1811	120	4.7244	77.23	3.041	1	0.04
TSL105	105	4.1339	105.5	4.154	140	5.5118	145	5.7087	30.0	1.1811	120	4.7244	76.30	3.006	1	0.04
TSL110	110	4.3307	110.5	4.350	145	5.7087	150	5.9055	30.0	1.1811	148	5.8268	106.89	4.208	1	0.04

SINGLE-DIRECTION, SELF-ALIGNING TYPE, MEDIUM SERIES

Bearing No.	Inside Diameter *B*		Diameter *C*		Outside Diameter *D*		Diameter *E*		Height *H*		Radius *R*		*X*		Chamfer or Radius *r* Minimum	
	Mm.	In.	Mm.	In.	Mm.	In.	Mm.	In.	Mm.	In.	Mm.	In.	Mm.	In.	Mm.	In.
TSM10	10	0.3937	11	0.433	30	1.1811	35	1.3780	15	0.5906	25	0.9843	9.91	0.389	1.0	0.04
TSM12	12	0.4724	13	0.512	32	1.2598	37	1.4567	16	0.6299	27	1.0630	10.65	0.418	1.0	0.04
TSM15	15	0.5906	16	0.630	35	1.3780	38	1.4961	17	0.6693	30	1.1811	12.31	0.483	1.0	0.04
TSM17	17	0.6693	18	0.709	38	1.4961	42	1.6535	18	0.7087	35	1.3780	16.80	0.659	1.0	0.04
TSM20	20	0.7874	21	0.827	40	1.5748	45	1.7717	18	0.7087	35	1.3780	16.26	0.638	1.0	0.04
TSM25	25	0.9843	26	1.024	48	1.8898	50	1.9685	19	0.7480	40	1.5748	12.54	0.492	1.0	0.04
TSM30	30	1.1811	31	1.221	53	2.0866	59	2.3228	20	0.7874	45	1.7717	16.09	0.631	1.0	0.04
TSM35	35	1.3780	36	1.417	62	2.4409	67	2.6378	23	0.9055	50	1.9685	23.30	0.914	1.5	0.06
TSM40	40	1.5748	41	1.614	64	2.5197	69	2.7165	23	0.9055	50	1.9685	22.49	0.882	1.5	0.06
TSM45	45	1.7717	46	1.811	73	2.8740	78	3.0709	27	1.0630	60	2.3622	28.71	1.126	1.5	0.06
TSM50	50	1.9685	51	2.008	78	3.0709	83	3.2677	27	1.0630	65	2.5591	33.12	1.299	1.5	0.06
TSM55	55	2.1654	56	2.205	88	3.4646	94	3.7008	30	1.1811	70	2.7559	32.53	1.276	1.5	0.06
TSM60	60	2.3622	61	2.402	90	3.5433	96	3.7795	30	1.1811	75	2.9528	38.14	1.496	1.5	0.06
TSM65	65	2.5591	66	2.598	100	3.9370	105	4.1339	34	1.3386	80	3.1496	38.65	1.516	2.0	0.08
TSM70	70	2.7559	71	2.795	103	4.0551	109	4.2913	34	1.3386	85	3.3465	42.78	1.678	2.0	0.08
TSM75	75	2.9528	76	2.992	110	4.3307	114	4.4882	34	1.3386	90	3.5433	46.38	1.819	2.0	0.08
TSM80	80	3.1496	81	3.189	115	4.5276	124	4.8819	37	1.4567	95	3.7402	48.78	1.913	2.0	0.08
TSM85	85	3.3465	86	3.386	125	4.9213	138	5.4331	40	1.5748	105	4.1339	55.08	2.160	2.0	0.08
TSM90	90	3.5433	91	3.583	135	5.3150	141	5.5512	40	1.5748	110	4.3307	57.63	2.260	2.5	0.10
TSM95	95	3.7402	96	3.780	140	5.5118	151	5.9449	43.5	1.7126	115	4.5276	60.48	2.372	2.5	0.10
TSM100	100	3.9370	101	3.976	150	5.9055	156	6.1417	44	1.7323	125	4.9213	69.25	2.716	2.5	0.10
TSM105	105	4.1339	106	4.173	155	6.1024	163	6.4173	49	1.9291	130	5.1181	69.33	2.719	2.5	0.10
TSM110	110	4.3307	111	4.370	160	6.2992	170	6.6929	49	1.9291	135	5.3150	74.00	2.902	2.5	0.10
TSM115	115	4.5276	116	4.567	165	6.4961	173	6.8110	52	2.0472	140	5.5518	75.40	2.957	3.0	0.12
TSM125	125	4.9213	126	4.961	180	7.0866	186	7.3228	56	2.2047	150	5.9055	80.12	3.142	3.0	0.12
TSM140	140	5.5118	141	5.551	200	7.8740	212	8.3464	62	2.4409	170	6.6929	84.53	3.315	3.0	0.12

SINGLE-DIRECTION, SELF-ALIGNING TYPE, HEAVY SERIES

Bearing No.	Inside Diameter *B*		Diameter *C*		Outside Diameter *D*		Diameter *E*		Height *H*		Radius *R*		*X*		Chamfer or Radius *r* Minimum	
	Mm.	In.	Mm.	In.	Mm.	In.	Mm.	In.	Mm.	In.	Mm.	In.	Mm.	In.	Mm.	In.
TSH25	25	0.9843	26	1.024	52	2.0472	55	2.1654	22	0.8661	45	1.7717	21.60	0.850	1.0	0.04
TSH30	30	1.1811	31	1.221	60	2.3622	65	2.5591	24	0.9449	55	2.1654	28.91	1.138	1.0	0.04
TSH35	35	1.3780	36	1.417	68	2.6772	75	2.9528	27	1.0630	60	2.3622	29.85	1.175	1.5	0.06
TSH40	40	1.5748	41	1.614	76	2.9921	85	3.3465	30	1.1811	65	2.5591	30.60	1.204	1.5	0.06
TSH45	45	1.7717	46	1.811	85	3.3465	95	3.7402	33	1.2992	75	2.9528	37.12	1.461	1.5	0.06
TSH50	50	1.9685	51	2.008	92	3.6220	100	3.9370	36	1.4173	80	3.1496	38.23	1.505	1.5	0.06
TSH55	55	2.1654	56	2.205	100	3.9370	110	4.3307	39	1.5354	90	3.5433	46.11	1.815	1.5	0.06
TSH60	60	2.3622	61	2.402	106	4.1732	115	4.5276	41	1.6142	90	3.5433	42.69	1.680	1.5	0.06
TSH65	65	2.5591	66	2.598	112	4.4094	120	4.7244	42	1.6535	100	3.9370	51.57	2.030	2.0	0.08
TSH70	70	2.7559	71	2.795	120	4.7244	130	5.1181	44	1.7323	100	3.9370	47.35	1.887	2.0	0.08
TSH75	75	2.9528	76	2.992	128	5.0394	140	5.5118	47	1.8504	110	4.3307	54.14	2.131	2.0	0.08
TSH80	80	3.1496	81	3.189	136	5.3543	145	5.7087	50	1.9685	120	4.7244	61.50	2.421	2.0	0.08
TSH85	85	3.3465	86	3.386	145	5.7087	155	6.1024	54	2.1260	125	4.9213	61.41	2.417	2.0	0.08
TSH90	90	3.5433	91	3.583	155	6.1024	165	6.4961	57	2.2441	135	5.3150	67.57	2.660	2.5	0.10
TSH95	95	3.7402	96	3.780	165	6.4961	175	6.8898	61	2.4016	135	5.3150	60.75	2.393	2.5	0.10
TSH100	100	3.9370	101	3.976	172	6.7716	185	7.2835	64	2.5197	140	5.5118	61.66	2.427	2.5	0.10
TSH105	105	4.1339	106	4.173	180	7.0866	195	7.6772	67	2.6373	145	5.7087	68.57	2.502	2.5	0.10
TSH110	110	4.3307	111	4.370	190	7.4803	205	8.0709	70	2.7559	160	6.2992	74.84	2.946	2.5	0.10

Gasoline Engine Division

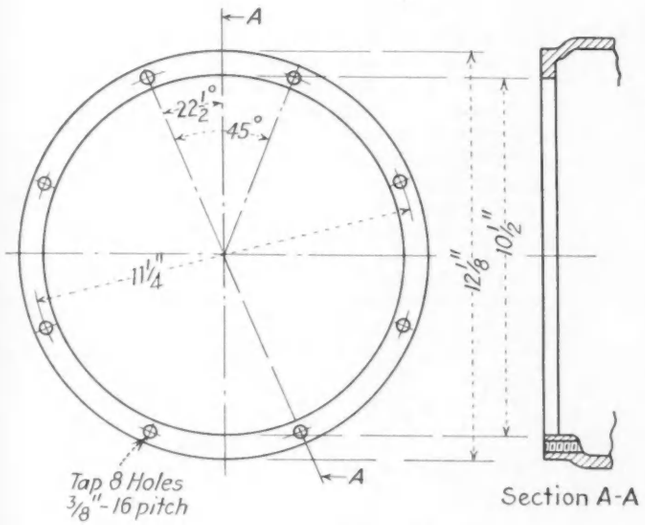
PERSONNEL

E. S. Marks, *Chairman*	H. H. Franklin Mfg. Co.
J. B. Fisher, *Vice-Chairman*	Waukesha Motor Co.
R. J. Broege	International Engineering Corp.
E. D. Herrick	Lycoming Mfg. Co.
Lewis P. Kalb	Continental Motors Corp.
E. T. Larkin	Sterling Engine Co.
A. F. Milbrath	Wisconsin Motor Mfg. Co.
Harold G. Smith	Hercules Motors Corp.
Ralph R. Teetor	Perfect Circle Co.
Vincent C. Young	International Motor Co.

Flywheel and Clutch Housings

(*Proposed Extension of S.A.E. Standard*)

At the suggestion of one of the large manufacturers of gasoline engines, a proposed No. 6 flywheel housing was circularized among the members of the Gasoline and Diesel Engine Divisions and other manufacturers to whom the proposal would be of interest. The Diesel-engine manufacturers indicated that the proposal is of little interest to them as this size is too small for Diesel-engine use. The gasoline-engine manufacturers likewise indicated that there will be only a limited use for this size on gasoline engines, but that where it is used it should follow an S.A.E. Standard. Accordingly the accompanying dimensions are submitted for adoption and inclusion in the present Standard, p. 77 of the 1931 S.A.E. HANDBOOK.



Motorcoach and Motor-Truck Division

PERSONNEL

A. W. Herrington, *Chairman*	Marmon-Herrington Co.
A. Gelpke, *Vice-Chairman*	Autocar Co.
W. J. Baumgartner	Relay Motors Corp.
M. C. Horine	International Motor Co.
G. B. Ingersoll	Federal Motor Truck Co.
L. C. Josephs, Jr.	International Motor Co.
F. W. Kateley	American Car & Foundry Motors Co.
W. F. Klein	General Motors Truck Co.
A. A. Lyman	Public Service Coordinated Transport
J. A. Packard	Studebaker Corp.
L. H. Palmer	Fifth Ave. Coach Co.
A. J. Scaife	White Co.
E. M. Schultheis	Timken Roller Bearing Co.
P. V. C. See	Akron Transportation Co.
T. C. Smith	American Telephone & Telegraph Co.
E. M. Sternberg	Sterling Motor Truck Co.

Uniform Motor-Vehicle Operating-Cost Classification

(*Proposed S.A.E. Recommended Practice*)

Originally the need for a uniform method of recording motor-vehicle operation and maintenance costs was suggested at the meeting of the Society's Operation and Maintenance Committee in New York City in October, 1925, at which time a Subcommittee was appointed to obtain data and study the subject. Classifications, forms and data were secured from a number of sources, such as the American Electric Railway Association and Public Utility Commissions in various States, all of which served the Subcommittee's purpose in a general way. After several meetings at which additional data and suggestions from various sources were discussed, a brochure entitled "The S.A.E. Accounting Study —Its Plan and Purpose" was circulated in July, 1927, to help secure cooperative interest in the work. A review of the Committee's activity up to that time was also published in the August, 1927, issue of THE JOURNAL. The first definite form for an accounting system, or what was more properly a classification of cost items, was developed by the Committee in August of that year. This form was discussed at a meeting of the Committee in Cleveland in October, 1927, which also met at that time with the A.E.R.A. Committee on Motorbus Accounting. The progress in this work was again reviewed in the December, 1927, issue of THE JOURNAL, and this was followed by a report on Motor Transport Accounting in the February, 1928, issue of the S.A.E. JOURNAL. The Committee felt that the investment in automobiles, trucks, tractors, garages, shops and equipment for motor-vehicle transportation has become so great that correctly accounting for the expense and the calculating of statistics in connection therewith is necessary to control motor-vehicle operation properly. Continued activity resulted in a report on Administrative Systems and Methods that was presented by L. V. Newton at the National Transportation Meeting of the Society at Newark, N. J., in October, 1928, as a result of which and the presentation of a paper by G. R. Gwynne entitled Motor-Vehicle Cost Accounting and Its Relationship to Economical Fleet-Operation at the meeting of the American Petroleum Institute in December, a report was prepared by Mr. Newton outlining a definite classification of operating and maintenance cost items. This was studied by the Transportation and Maintenance Activity Committee of the Society which succeeded the Operation and Maintenance Committee, and circulated for comments. This thorough review of the work that had been prepared led the 1930 Transportation and Maintenance Activity Committee to vote at its final meeting on Jan. 20, 1931, to recommend the report to the Standards Committee through the Motorcoach and Motor-Truck Division, for adoption and publication in the S.A.E. HANDBOOK. The 1931 Committee at its meeting immediately following that of the 1930 Committee confirmed the action taken on the report. The accompanying classification was subsequently referred to the Motorcoach and Motor-Truck Division of the Standards Committee and is submitted herewith, subject to approval by the Motorcoach and Motor-Truck Division of the Standards Committee, for consideration by the Society looking to its adoption as S.A.E. Recommended Practice. The Transportation and Maintenance Committee believes that the Society can do real constructive work by establishing a uniform method by outlining for, and educating motor-vehicle owners and operators, as to what constitutes cost of operating motor-vehicles. The accompanying recommendation is made after a thorough study of

many accounting schemes employed in various businesses, the basic idea being to present a plan that is applicable to all lines of work and which, if adopted, will make possible a comparison of one company's costs with those of another and will show the operator exactly what his operation is costing.

Introduction

The recommendation of a uniform classification of accounting cost items does not necessarily mean that, to follow this classification, the accounts must be kept as set forth. It is recognized that companies are keeping their accounts in accordance with accounting orders of regulatory bodies and that the classification of accounts may not permit all charges to be made as outlined herein. This, however, will not prevent the assembling of the information necessary to prepare the costs as classified.

In regard to reducing costs to the proper basis for final analysis, the method commonly used is to figure costs on a mileage or an hourly basis. Some companies base their costs on a tonnage, gallonage, or poundage basis. Each company must decide for itself the basis on which it wants to calculate cost. In public-utility work, the cost per hour is considered most suitable. In certain hauling work, the cost per ton, or ton-mile would be best.

Although no standard scheme can be recommended for use by all companies, use of the following classification will make it possible for operators to know more accurately what their operations are costing them. It is recommended that all costs be kept by individual vehicles. While this may seem unduly laborious and expensive, the results obtained will justify the expense incurred. Only by knowing the exact cost of operating each vehicle can the most economical and efficient unit be determined, and the operator be in position to know exactly what he is doing. This can be done conveniently by assigning a number to each vehicle. The numbers can be assigned to classes of vehicle by series, so that the number will indicate the type of vehicle; or they can be assigned in rotation as the vehicles are acquired.

Classified Items of Cost

(1) *Gasoline or Electric Energy.*—Charge (*a*) cost of gasoline used as fuel, or electric energy used as power in the operation of each vehicle; (*b*) freight and handling charges if the fuel is purchased in tank-car lots. The cost of gasoline should include the gasoline tax. Electric energy should be charged as billed by the central power-station.

(2) *Oil.*—Charge (*a*) cost of motor oil used for engine lubrication; (*b*) transportation and handling charges. The cost of transmission lubricants and greases is not charged to this account but to account No. 11, Garage Material, as it is extremely difficult to measure accurately the quantities used for lubricating each vehicle.

(3) *Tires and Tire Repairs.*—Charge (*a*) cost of all pneumatic casings, inner tubes and solid or cushion tires used for renewal purposes; (*b*) cost of labor for removing old and installing replacement tires; (*c*) cost of labor and material used in conjunction with repairing pneumatic casings and tubes; and (*d*) money paid for tire usage if tire mileage is purchased, either at a flat sum per month or on a cost-per-mile basis. The cost of spare pneumatic casings and tubes purchased for new vehicles is not charged against this account but against investment in the vehicle. When spare casings and tubes are renewed, however, the renewal cost is chargeable to this account.

Credit (*a*) any monies received on account of the sales of tires and tubes as junk; and (*b*) any monies received from tire companies on adjusted tires, that is, tires which did not deliver expected mileage.

(4) *Repair Material Used on Chassis.*—Charge (*a*) cost of all parts or material used in conjunction with repairing the chassis of each vehicle because of ordinary wear and tear and not of accidents; (*b*) cost of any parts or material used on a vehicle at the time of inspection. The cost of repair parts or material used as a result of accidents is not chargeable to this account but to account No. 9, Accident, Labor and Material.

Credit (*a*) any monies received from the sale of worn-out parts or material as junk; and (*b*) any monies received as credits allowed by the manufacturer on account of defective parts.

(5) *Repair Material Used on Superstructure.*—Charge (*a*) cost of all parts or material used in repairing the cab, body, or such auxiliary equipment as winches, pumps or derricks used on each vehicle, when the repairs are due to ordinary wear and tear and not to accidents; (*b*) cost of repair parts or material used on the vehicle at the time of inspections. The cost of repair parts or material used as a result of accidents is not chargeable to this account but to account No. 9, Accident Labor and Material.

Credit (*a*) any monies received from the sale of worn-out parts or material as junk; (*b*) any monies received as credits allowed by the manufacturer on account of the return of defective parts.

(6) *Repair Labor Used on Chassis.*—Charge (*a*) cost, including shop-overhead charges, of all labor used for repairing the chassis of each vehicle because of ordinary wear and tear and not of accidents; (*b*) cost of labor used in making inspections of the chassis.

(7) *Repair Labor Used on Superstructure.*—Charge (*a*) cost, including shop-overhead charges, of all labor used for repairing the cab, body or auxiliary equipment on each vehicle, as a result of ordinary wear and tear and not of accidents; (*b*) cost of labor used in making inspections of the cab, body or auxiliary equipment.

(8) *Painting Labor and Material.*—Charge (*a*) cost of all materials used for painting the chassis, cab, body and all auxiliary equipment of the vehicles; (*b*) cost of all labor used in painting the foregoing; (*c*) paint-shop overhead-charges, if the work is done in a paint shop owned by the vehicle operator, which charge will be defined later. Any painting work due to accidents should be charged to account No. 9, Accident Labor and Material. When new vehicles are purchased and are painted by the operator in his distinctive colors before being placed in service, such painting is not chargeable to this account but to the investment in new vehicles.

(9) *Accident Labor and Material.*—Charge total cost of all material and labor, including overhead charges, used in conjunction with restoring a vehicle to service after it has met with an accident. By "accident" is meant collision,

fire or theft, on which an accident report is made or a case is reported to the insurance company.

Credit any monies received from the insurance company, or others, as reimbursement for damages sustained to vehicles or for theft of vehicles.

(10) *Garage Labor.*—Charge all garage labor used in washing, polishing, oiling and greasing vehicles, inflating tires, filling radiators, putting water in batteries and all garage work of this nature.

(11) *Garage Material.*—Charge (*a*) cost of material, the cost of any one item of which is too small to account for individually or the quantity used on each vehicle would be difficult to determine. The items to be included are: grease, transmission oil, penetrating oil, antifreeze solution, battery water, rags, waste, sponges, chamois, nickel polish, body polish, soap, kerosene, boots, rubber aprons, hose and the like; (*b*) cost of upkeep of equipment in the garage independently of the repair-shop, such as equipment for electric charging, gasoline and oil storage and dispensing, washing, compressing air and the like.

(12) *Miscellaneous Expense.*—Charge extraordinary expense incurred in operating motor-vehicle which is not provided for in the foregoing accounts and is not chargeable to each vehicle. This includes tire changes, drivers' uniforms, gloves, robes and so on.

(13) *Drivers' and Helpers' Wages.*—Charge cost of drivers' and helpers' wages and incidental expenses.

(14) *Garage Rent and Maintenance.*—Charge (*a*) rental paid for and cost of maintenance of garage buildings; (*b*) charge for storage of vehicles in public garages. In the case of property owned by the vehicle-operating company, an amount can be set as rental which includes taxes, insurance, maintenance, water and retirement of and interest on investment in both land and buildings. The total rental can then be prorated to all the vehicles garaged in the building according to the space each occupies. If the garage occupies only a portion of the building, a rental should be charged on the basis of the floor area used for garage purposes. In the case of rented vehicles, insurance carried on the garage and its equipment should be included with the rental in prorating against the individual vehicle.

(15) *Insurance.*—Charge cost of all classes of insurance carried on the vehicles, such as premiums on fire, theft, property-damage, collision and public-liability insurance. Only the cost of insurance coverage on vehicles is charged to this account, as insurance on company-owned garage buildings is included in account No. 14, Garage Rent and Maintenance, and any insurance carried on employes is chargeable to account No. 20, Overhead Expense.

(16) *Licenses and Taxes.*—Charge (*a*) cost of all motor-vehicle licenses and taxes assessed by the State, city and county; (*b*) cost of drivers' licenses, if these are paid for by the operating company.

(17) *Depreciation.*—Charge an amount monthly on each vehicle as depreciation.

(18) *Superintendence.*—Charge (*a*) salary of the superintendent of transportation or such other employe as may have direct jurisdiction over the operation and maintenance of motor-vehicles; (*b*) salaries of vehicle dispatchers, record and accounting clerks and garage superintendents, in accordance with the time each spends on such work.

(19) *Interest.*—Charge interest on the investment in motor-vehicles; that is, their original cost less depreciation. It is customary to use the rate of 6 per cent in computing interest charges. Interest on garage buildings and equipment is not chargeable to this account, but to account No. 14, Garage Rent and Storage, or to account No. 20, Overhead Expense.

(20) *Overhead Expense.*—The charges for garage overhead are (*a*) watchmen's wages, covering garage; (*b*) porter's wages, cleaning garage; (*c*) cost of insurance on garage equipment; (*d*) taxes and permits on garage building and equipment; (*e*) cost of electric light and power; (*f*) cost of fuel for heating; (*g*) cost of operation of the automobile used by the superintendent of transportation; (*h*) lost time of garage employes due to vacation, sickness or leave of absence with pay; and (*i*) cost of brooms, floor brushes, coal shovels, hand soap, mop handles, mops, paper towels, ice, drinking water, fire extinguishers, lamp globes used for maintenance and the like.

The charges for shop overhead are (*a*) shop foreman's salary; (*b*) watchman's wages, covering shop; (*c*) porter's wages, cleaning shop; (*d*) cost of insurance on shop equipment; (*e*) cost of electric light and power; (*f*) cost of fuel for heating; (*g*) cost of water; (*h*) cost of operation of the automobile used for picking up repair parts; (*i*) wages of shop employe whose time is used for picking up repair parts; (*j*) cost of operation of towing or wrecking car, if such a car is used; (*k*) cost of small-tool replacements; (*l*) upkeep repairs and depreciation on shop machinery and equipment; (*m*) lost time of shop employes due to vacation, sickness or leave of absence with pay; and (*n*) cost of acid, blacksmith coal, top binding, hacksaw blades, Prussian blue, taps, cotter-pins, curtain fasteners, emery cloth, tire cement, valve-grinding compound, drills 0-¼ in., flux, fuses, friction tape, washers, files, graphite, governor wire and seals, glue, hammer handles, laminated shims, nails, neatsfoot oil, penetrating oil, oxygen, pump packing, welding rods, rivets, insulated staples, stovepipe wire, sandpaper, shellac, solder, upholstery tacks and the like.

For stores, the charges are (*a*) salaries of stock men or storekeepers; (*b*) cost of space occupied for stockroom purposes; and (*c*) interest on investment in repair parts and material, and any other stores expense of this nature.

(21) *Administrative Expense.*

Charge cost of office rent, telephone, postage, stationery and supplies, depreciation of furniture and fixtures, legal expense, automobile expense and other administrative expenses of this nature.

Variable and Fixed Costs

The foregoing classification covers all items of motor-vehicle expense except, possibly, some items

that are special to hauling companies, such as selling expense, advertising and the like.

The various items of expense thus classified may be grouped under the two major headings of Variable Expense and Fixed Expense. It should be understood that the various classifications can be combined in any way that the operator chooses, the main consideration being that all items of expense be included. The suggested grouping follows:

Variable Operating Expense

(1) Gasoline or electric energy
(2) Oil
(3) Tires and tire repairs
(4) Repair material used on chassis
(5) Repair material used on cab, body or auxiliary equipment
(6) Repair labor used on chassis
(7) Repair labor used on cab, body or auxiliary equipment
(8) Painting labor and material
(9) Accident labor and material
(10) Garage labor
(11) Garage material
(12) Miscellaneous expense

Fixed Operating Expense

(13) Drivers' and helpers' wages
(14) Garage rent and maintenance
(15) Insurance for vehicles
(16) Licenses and taxes on vehicles
(17) Depreciation on vehicles
(18) Superintendence
(19) Interest on investment in vehicles
(20) Overhead; garage, shop and stores
(21) Administrative expense

Record Forms Required

The securing of costs will make it necessary that the following forms be established:

Drivers' Daily Time-Card.—This should indicate the time each vehicle leaves and the time it returns to the garage; the number of trips made; the mileage of each trip; total mileage for the day; number of gallons of gasoline and quarts of oil put in; any expenses incurred during the day exclusion of gasoline, oil or repairs made in company-owned garages; and the pounds, tons or gallons of material handled.

Tire-Change Report.—This should indicate any tires changed during the day on pneumatic-tired vehicles, the location of the tire change and the mileage at the time the change was made.

The Driver's Daily Time-Card and the Tire-Change Report are the only reports drivers should be asked to make other than reports of accidents, the need of which is obvious.

The following forms should be used in garages and shops:

Daily Time-Card.—On this form should be recorded the time of each garage man, mechanic or other persons employed in the shop and the garage.

Material Requisition.—Material withdrawn from the stockroom and the vehicle number and the job number on which it is to be used should be recorded on this form.

Repair-Shop Job-Order.—This form is needed so that instructions can be issued properly to mechanics and others working in the repair-shop, outlining in detail exactly the work to be performed on each vehicle. If a job number is assigned to this form, all expenses on each job can be accumulated upon completion of the job by making certain that the job number is shown on all labor and material expenditures and withdrawals.

Daily Gasoline and Oil Report.—This record should indicate the gasoline and oil consumption of each vehicle. Space can also be provided so that alcohol or antifreeze consumption can be shown.

Tire Record.—This form should be kept so that the performance of each solid tire and each pneumatic casing can be ascertained accurately.

Stock-Record Card.—To operate the stockroom properly, a stock record-card of the perpetual-inventory type should be kept. When this is posted from day to day, it will indicate the quantities of each kind of material on hand at the close of each day.

Depreciation Defined

Depreciation account No. 17 is defined as the decline in value of a tangible property because of an aggregation of causes, such as wear and tear, obsolescence from age, new inventions, public requirements and the like, and to casualties. Being of the nature of an operating loss, depreciation must be provided for by charges to operating expense. The amount of depreciation to be charged against each vehicle per month can be arrived at by computing it on the life of the vehicle expressed in months or in total miles each vehicle is to be run during its life.

If depreciation is computed on a monthly basis, the total first cost of the vehicle, this cost to include chassis, cab, body, accessories, freight, painting and the like, is divided by the total number of months it is estimated the vehicle will run. For example, if the total first cost of the vehicle is $4,000 and its estimated life is 48 months, then $83.33 per month should be charged as depreciation.

If vehicles are depreciated on a mileage basis, the total first cost of the vehicle is divided by the estimated life in miles the vehicle will run, and depreciation is charged each month on the basis of the mileage it is operated in that month. For example, if the first cost is $4,000 and the estimated life of the vehicle is 50,000 miles, the depreciation rate per mile should be 8 cents. If the vehicle were operated 1000 miles in a month, the depreciation to be set up against the vehicle that month would be $80.

Bases for Computing Depreciation

The rate of depreciation must be computed for each line of business, depending upon the nature of the roads traversed and the conditions under which transportation is conducted. In most lines of transportation work, the mileage basis of computing depreciation is the more equitable, but for operations where the mileage is abnormally low, depreciation should be set up on a monthly basis rather than on a mileage basis, although, if desired, depreciation may be set up on a mileage basis, caution being used to make the rate per mile high enough.

Motor-Truck Chassis-Dimensions

(Proposed S.A.E. Recommended Practice)

At the meetings of the Motorcoach and Motor-Truck Activity and the Transportation and Maintenance Activity Committees of the Society in January, 1930, each Committee appointed a Subcommittee to study Motor-Truck Standardization Requirements along the lines suggested in the paper on Trend of Weight and Size in the Development of Motor-Trucks and Motorcoaches that was presented before the Society by Pierre Schon. The Committees selected the width of motor-truck frames and the distance from the back-of-cab to the center line of rear axle as the essential dimensions for chassis standardization and to permit of standardizing motor-truck body-mountings. Further study by the Committees led to crystallization of the project during the year. In the meantime, the Motor-Truck Committee of the National Automobile Chamber of Commerce was considering the standardization of frame widths and lengths for commercial vehicles, and this proposal, together with one drafted by the American Petroleum Institute, were discussed at the meeting of the American Petroleum Institute in Chicago in last November. As a result, the Na-

tional Automobile Chamber of Commerce Motor-Truck Committee delayed final action on its proposal that had been scheduled for about the same time, pending further consideration by the several groups interested.

A joint meeting of the N. A. C. C. Motor-Truck Committee and the Motor-Truck Standardization-Requirements Subcommittees of the S.A.E. Transportation and Maintenance Activity and the Motorcoach and Motor-Truck Activity Committees was held in New York City on Jan. 6, 1931, at which a tentative proposal was discussed and referred to the Society with the recommendation that it be taken up by a Subdivision on Motor-Truck Chassis to be appointed under the Motorcoach and Motor-Truck Division of the Standards Committee. A meeting of this Subdivision, together with the Subcommittees of the two Activity Committees was held in Detroit on Jan. 22 of this year and was attended by representatives of most of the larger motor-truck manufacturers and a number of the larger operators. The data that had been accumulated were reviewed and a proposed series of dimensions from back-of-cab to center line of rear axle was drafted that met with the approval of those present as the basis for future standardized truck-length dimensions. The matter of frame widths was likewise discussed and a proposal voted upon favorably. In view of the consideration that has been given the proposal by the motor-truck manufacturers and many of the operators, these proposals are accordingly printed in this issue of THE JOURNAL for submission through the Motorcoach and Motor-Truck Division, to the Standards Committee and Society for approval and adoption as S.A.E. Recommended Practice. Such approval at this time will avoid delaying final action by the Society on the report until January next year and will give both the motor-truck manufacturers and operators a definite basis on which to consider the manufacture and purchase of future motor-truck equipment. At the time of publishing this report, it was subject to confirmation by the Motorcoach and Motor-Truck Division. The recommendation follows:

(1) The nominal frame-width for motor-trucks shall be 34 in. with a maximum plus tolerance of 5/8 in., and a minus tolerance of zero.

(2) The *BA* dimensions, distance from back-of-cab to center line of rear axle, of motor trucks shall be 39, 48, 60, 72, 84, 102, 120, 138 and 156 in.

Parts and Fittings Division

PERSONNEL

A. Boor, *Chairman*	Willys-Overland Co.
Ivan Ornberg, *Vice-Chairman*	Hupp Motor Car Corp.
A. K. Brumbaugh	White Motor Co.
Herbert S. Jandus	Lyon Cover Co.
W. C. Keys	Detroit, Mich.
E. F. Lowe	Handy Governor Corp.
G. L. McCain	Chrysler Corp.
M. B. Morgan	Timken-Detroit Axle Co.
Harold Nutt	Borg & Beck Co.
W. J. Outcalt	General Motors Corp.
C. W. Spicer	Spicer Mfg. Corp.
C. E. Swenson	Mechanics Universal Joint Co.
P. L. Tenney	Muncie Products Division of the General Motors Corp.
S. O. White	Warner Gear Co.
G. W. Yanss	Bridgeport Brass Co.
O. B. Zimmerman	International Harvester Co.

The work of the Parts and Fittings Division during the first half of this year has consisted mainly of reviewing S.A.E. Standards and Recommended Practices that have been reported by the Division in the past as many of them have not been reviewed for a number of years and have become either obsolete or out of date. The subjects reported below were reviewed at the meeting of the Division held last month in Detroit and are submitted herewith for action as indicated under each subject. Several other subjects are also being reviewed but it was felt they could not be reported at the time of the Summer Meeting this month and so will be reported at the Annual Meeting next January in time for inclusion in the 1932 edition of the S.A.E. HANDBOOK.

Rod Ends and Pins

(*Proposed Revision of S.A.E. Standard*)

The only revisions proposed in the present S.A.E. Standard, pp. 250 to 252 of the 1931 S.A.E. HANDBOOK, are as recommended below for adoption by the Society.

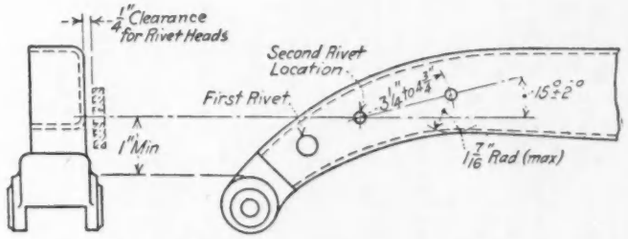
(1) Add tolerance plus or minus 0.010 for the width between prongs in the clevis and plus 0.000, minus 0.010 for the width of the eye. The same tolerances apply also to dimension *B* for tie-rod fittings for cast type radiators, p. 95 of the 1931 S.A.E. HANDBOOK.

(2) Specify that the threads in the threaded clevis shall be American Standard (NF) Fine, Class 2 Fit.

Passenger-Car Bumpers

(*Proposed Revision of S.A.E. Standard*)

The Division recommends that the second part of the S.A.E. Standard, p. 300 of the 1931 S.A.E. HANDBOOK, relating to front-bumper mountings be cancelled as these dimensions apply now only to a few replacement jobs and are obsolete so far as the purpose of S.A.E. Standards is concerned. The specification to be cancelled is shown by the accompanying cut.



Two 33/64-in. diameter bolt-holes shall be located on or near the neutral axis of the frame section.

The first bolt-hole back from the spring eye may coincide with the first or second rivet-hole.

In cases where the second bolt-hole is to be used for mounting a shock-absorbing device, the hole shall be located not more than 1-7/16 in. from the bottom of the frame channel at the nearest point.

Lock-Washers

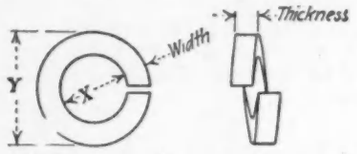
(*Proposed Revision of S.A.E. Standard*)

The original S.A.E. Standard that was adopted in 1911 and last revised in 1922 has been subject to considerable study by the Division as well as the Sectional Committee on Washers, of which the Society is one of the sponsors under the American Standards Association. Surveys have shown that the S.A.E. Standard is extensively used and that the great majority of washers used by the automotive industry, which are approximately 85 per cent of the total quantities manufactured, follow the standard.

The previous standard, pp. 245 to 247 inclusive of the 1931 S.A.E. HANDBOOK, was separated into four tables showing standard lock-washers for machine screws and bolts and special washers for machine screws and bolts respectively. In the accompanying recommendation these four tables have been consolidated to show standard lock-washers

without reference to machine screws or bolts as they are used also for locking other parts, but the nominal sizes follow the screw and bolt standards with the exception of the 11/16-in. size which is retained as it is used extensively. The important changes are, first, the consolidation of the lock washers for the round-head and fillister-head machine-screws as the Division feels that with the present standard screw heads, only one series of washers is necessary; secondly, the revision of the paragraph specifying temper test.

It is expected that the American Standard for Lock Washers when completed by the Sectional Committee will embody the S.A.E. Standard for automotive use in accordance with the understanding that was had at the last meeting of the Sectional Committee. The Division accordingly recommends that the proposed revision of the present S.A.E. Standard be adopted.



LOCK-WASHERS—REGULAR, LIGHT AND HEAVY SERIES

Nominal Size	Inside Diameter Clearance Minimum	Inside Diameter X Minimum	Outside Diameter Y			Sections*					
						Regular		Light		Heavy	
			Regular	Light	Heavy	Width	Thickness	Width	Thickness	Width	Thickness
2(0.086)	0.003	0.089	0.151	0.133	0.151	1/32	0.022	0.022	0.022	1/32	1/32
4(0.112)	0.003	0.115	0.177	0.177	0.209	1/32	1/32	1/32	0.022	3/64	1/32
6(0.138)	0.005	0.143	0.237	0.205	0.237	3/64	1/32	1/32	1/32	3/64	3/64
8(0.164)	0.005	0.169	0.263	0.263	0.294	3/64	3/64	3/64	1/32	1/16	3/64
10(0.190)	0.010	0.200	0.325	0.294	0.325	1/16	3/64	3/64	3/64	1/16	1/16
12(0.216)	0.010	0.226	0.351	0.351	0.382	1/16	1/16	1/16	3/64	3/64	1/16
1/4	0.015	5/32	15/32	15/32	15/32	3/32	1/16	3/32	3/64	3/32	3/64
5/16	0.015	11/32	19/32	19/32	19/32	1/8	1/16	1/8	3/64	1/8	3/32
3/8	0.015	13/32	21/32	21/32	21/32	1/8	3/32	1/8	1/16	1/8	1/8
7/16	0.015	15/32	25/32	25/32	25/32	5/32	1/8	5/32	1/16	5/32	5/32
1/2	0.015	17/32	7/8	7/8	7/8	11/64	1/8	11/64	1/16	11/64	11/64
5/16	0.030	19/32	31/32	31/32	31/32	5/16	1/8	5/16	5/32	5/16	5/16
3/8	0.030	21/32	1 1/16	1 1/16	1 1/16	13/64	5/32	13/64	5/32	13/64	13/64
11/16	0.030	23/32	1 5/32	1 5/32	1 5/32	7/32	5/16	7/32	1/8	7/32	7/32
3/4	0.030	15/16	1 5/16	1 5/16	1 5/16	1/4	5/16	1/4	1/8	1/4	1/4
7/8	0.030	15/16	1 15/32	1 15/32	1 15/32	17/64	5/16	17/64	5/32	17/64	17/64
1	0.030	1 1/16	1 11/16	1 11/16	1 11/16	5/16	1/4	5/16	5/16	5/16	5/16
1 1/8	0.030	1 5/16	1 15/16	1 15/16	1 15/16	3/8	1/4	3/8	5/16	3/8	3/8
1 1/4	0.030	1 5/16	2 5/16	2 5/16	2 5/16	7/16	1/4	7/16	1/8	7/16	5/16
1 3/8	0.030	1 5/16	2 5/16	2 5/16	2 5/16	7/16	5/16	7/16	1/4	7/16	3/8
1 1/2	0.030	1 5/16	2 5/16	2 5/16	2 5/16	1/2	5/16	1/2	1/4	1/2	3/8

* Lock-washer sizes should be designated by giving the diameter, the width and the thickness of the lock-washer in the order given; as 1/2 x 11/64 x 1/8.

Tests

Temper Test.—After a first compression to flat, the free height of the lock-washer shall be at least 1⅔ times its thickness. Subsequent compressions shall not further reduce this free height.

Toughness Test.—Forty-five per cent of the lock-washer including one end, shall be secured firmly in a vise and 45 per cent including the other end, shall be secured firmly between parallel jaws of a wrench. Movement of the wrench at right angles to the helical curve shall twist the lock-washer through 45 deg. without it showing signs of fracturing, and shall twist the lock-washer entirely apart within 135 deg.

Screw Threads Division

PERSONNEL

E. H. Ehrman, *Chairman*	Standard Screw Co.
Earle Buckingham, *Vice-Chairman*	Massachusetts Institute of Technology
A. Boor	Willys-Overland Co.
E. J. Bryant	Greenfield Tap & Die Corp.
G. Carvelli	Wright Aeronautical Corp.
Geo. S. Case	Lamson & Sessions Co.
C. T. Doman	H. H. Franklin Mfg. Co.
R. M. Heames	Allied Products Corp.
Wm. E. John	Sterling Engine Co.
W. J. Outcalt	General Motors Corp.
L. L. Roberts	Packard Motor Car Co.
F. W. Stein	Fairbanks, Morse & Co.
S. B. Terry	Pratt & Whitney Co.
O. B. Zimmerman	International Harvester Co.

Slots in Plain Nuts

(*Proposed S.A.E. Recommended Practice*)

Some time ago the Division reviewed all of the S.A.E. Standards and Recommended Practices for Plain Nuts having slots to establish a definite standard for slotting in order to eliminate the variations in the product as well as to establish a standard for the slot saws or cutters. With the adoption of the American Standards for Plain Nuts as formulated by the Sectional Committee on Bolt, Nut and Rivet Proportions, a series of slot depths and widths was developed by the Division, the depths of the slots being figured on the basis of retaining 1½ times the nominal thread diameter plus a margin of safety below the bottom of the slot, the margin of safety increasing with the larger nut sizes. The proposal was reviewed and approved by the Division at its meeting held in Detroit on May 12 and is accordingly submitted for adoption as recommended practice as shown in the accompanying table.

PLAIN NUT SLOT DIMENSIONS

Nominal Nut Size	Nut Thickness	Slot Width	Slot Depth
1/4	7/32	5/64	3/32
5/16	17/64	5/64	7/64
3/8	21/64	1/8	1/8
7/16	3/8	1/8	9/64
1/2	7/16	1/8	11/64
9/16	1/2	5/32	11/64
5/8	35/64	5/32	13/64
3/4	21/32	5/32	7/32
7/8	49/64	5/32	1/4
1	7/8	5/32	9/32
1 1/8	1	7/32	5/16
1 1/4	1 3/32	7/32	5/16
1 1/2	1 5/16	1/4	3/8

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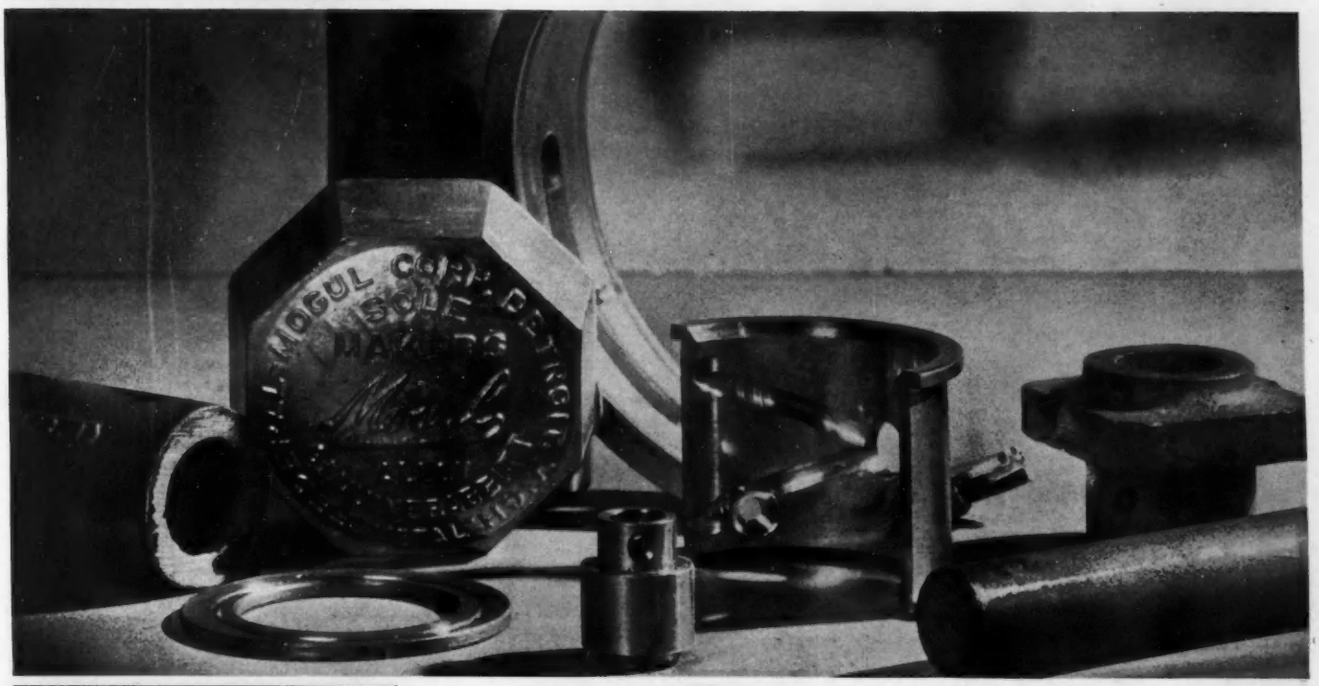

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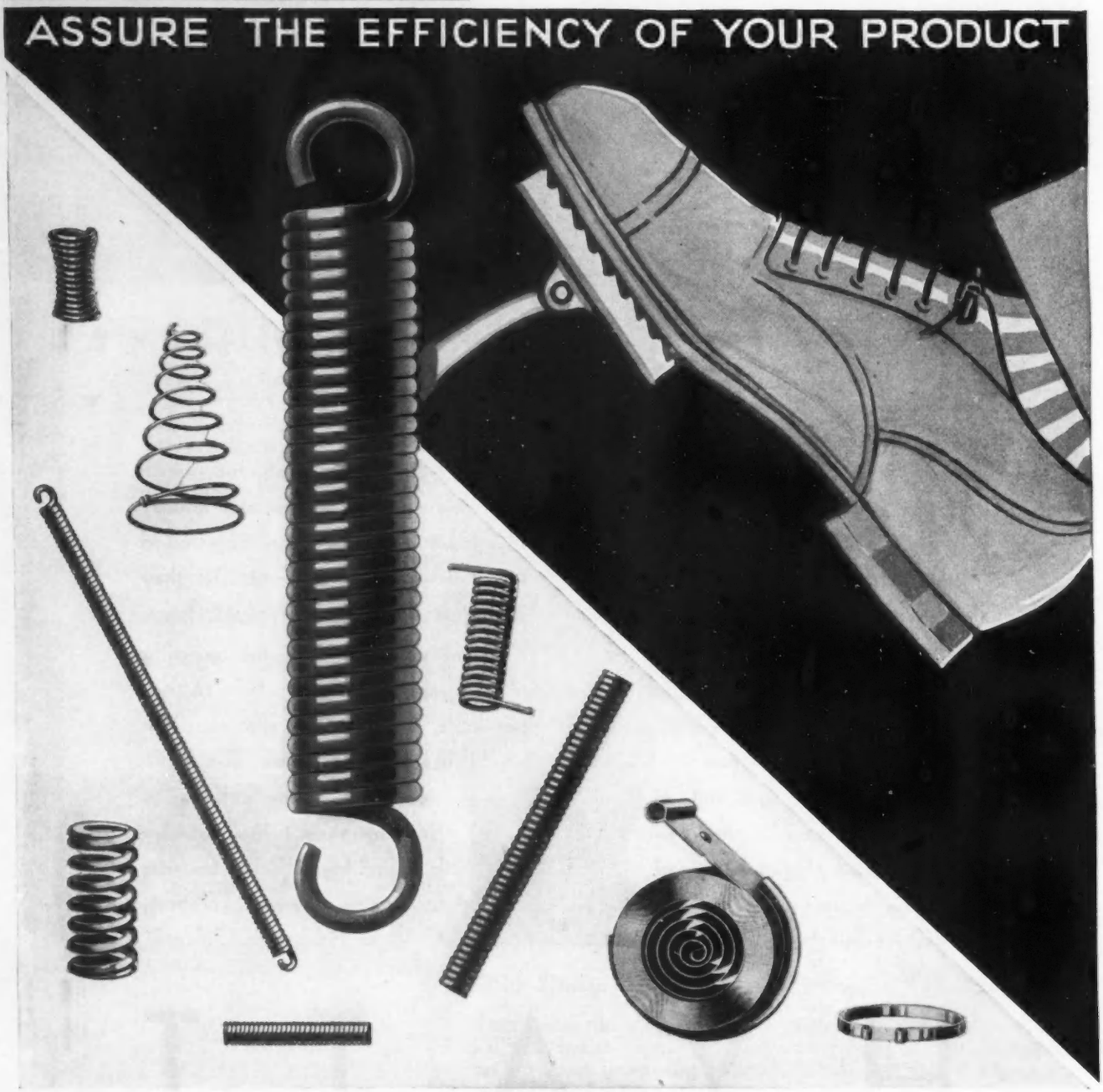

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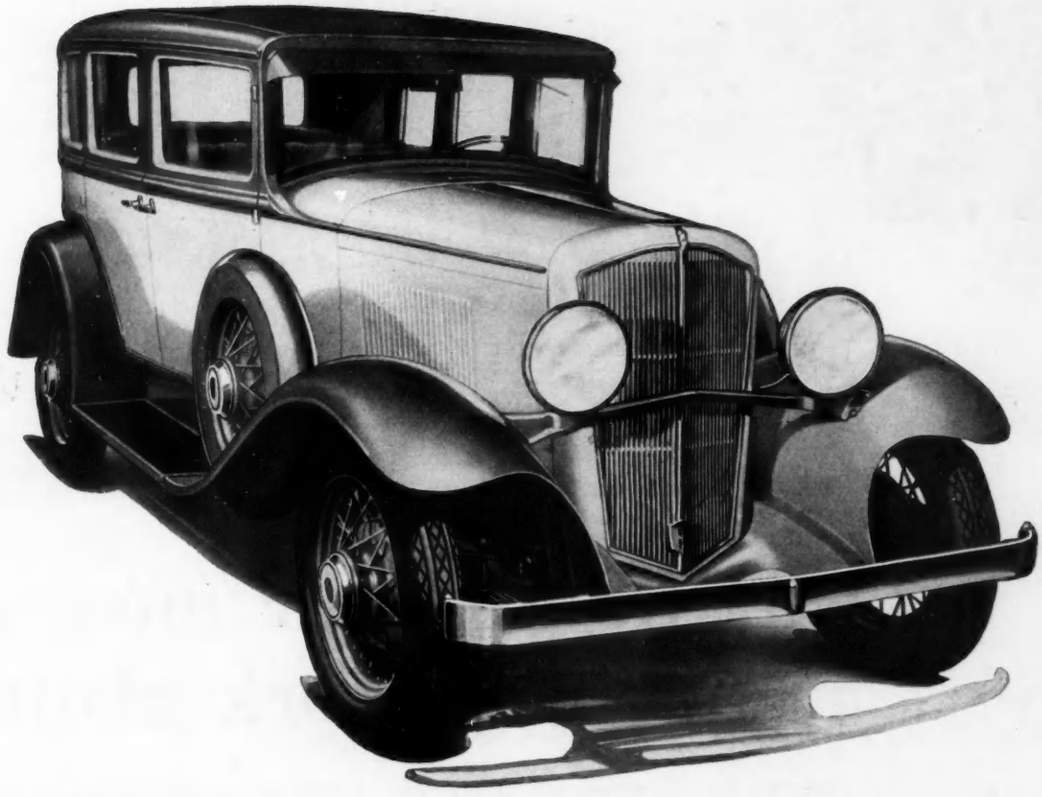
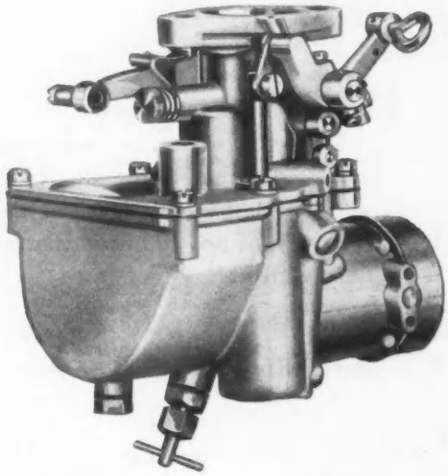
Pacific Coast Distributors: Columbia Steel Company, Russ Building, San Francisco *Export Distributors:* United States Steel Products Company, New York

The DeVaux Car adopts *Tillotson* carburetors as standard equipment



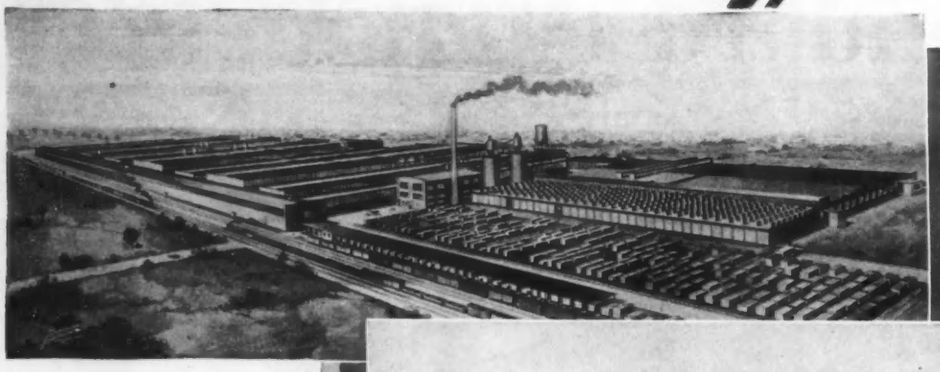


An exceptional car with exceptional carburetion. The Tillotson Manufacturing Company, Toledo, Ohio.

Tillotson

CARBURETORS

With these facilities available . .



Two complete plants devoted exclusively to the manufacture of body woodwork.

why tie up your money in a body woodwork plant?

One of the important advantages of using Mengel woodwork is that it frees capital tied up in machinery, lumber, dry kilns, etc.—capital that you can use for more profitable purposes.

Being relieved of the necessity of storing and machining the lumber in your own plant, you may devote your entire floor space to assembly or other work—you can produce the maximum number of bodies per dollar invested in your body building equipment.

You also get the immediate benefit of manufacturing economies that result from the superior facilities which Mengel has been able to develop by specializing in large-scale production of woodwork.

Every modern facility that lowers costs has been taken advantage of in equipping the Mengel plants.

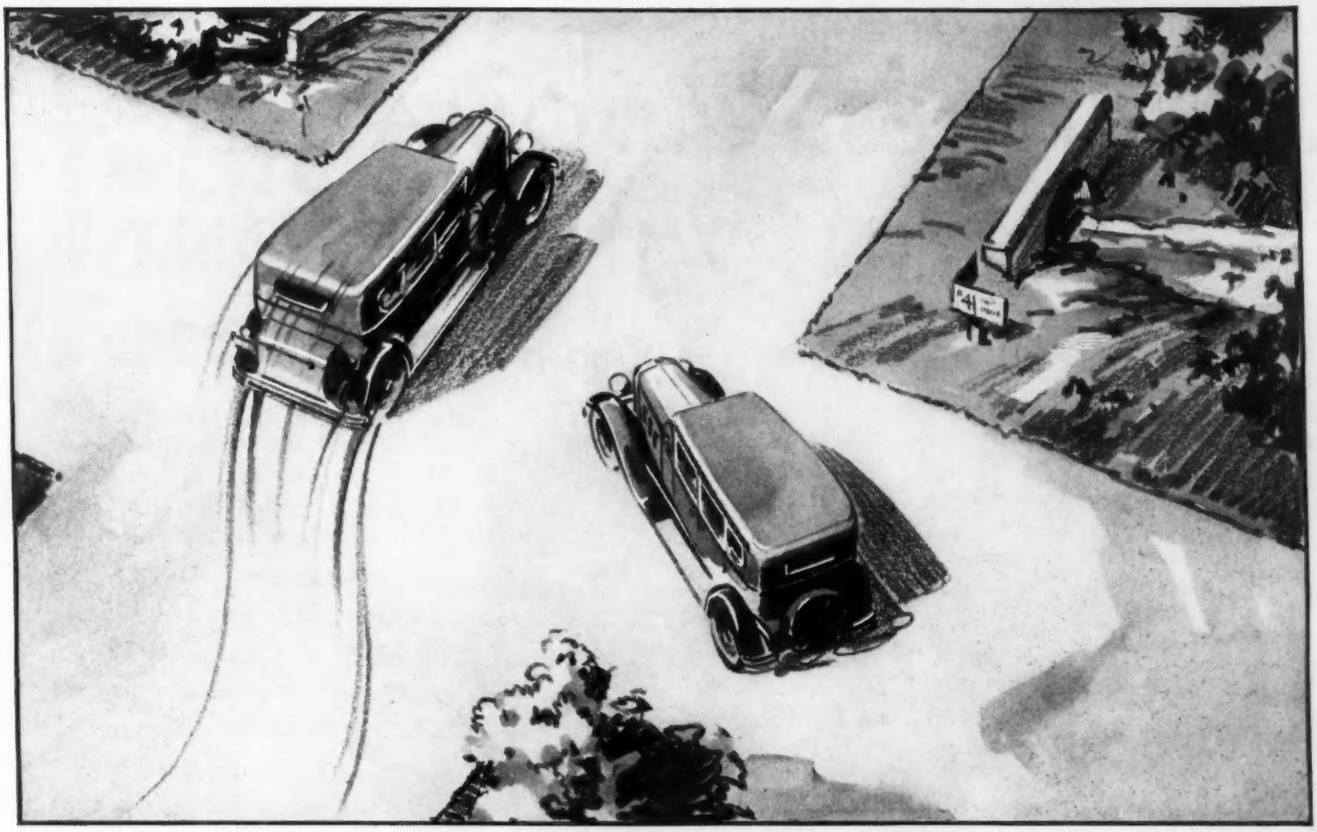
We have proved our economies in so many cases that we believe we can give you the same advantages we have given others. Why not go into this matter more fully with us?

THE MENGEL COMPANY, INC.
Automotive Division Louisville, Ky.

MENGEL BODY WOODWORK

saves money and worry

High Speeds *Demand* Instant Response

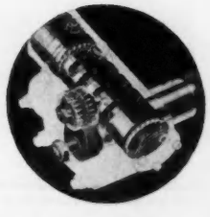


• *The higher the speed at which a car is driven, the more imperative it is to have* **accurate, instantly responsive,** *steering. At sixty or better there's no time to jockey the wheel and guess what the results will be.*

The Ross Roller-Mounted Cam and Lever Steering Gear is unequalled in ease of wheel-turn —the most accurate and instantly responsive instrument of steering that has ever been put in a driver's hands . . . Even more important is the fact that Ross steering effects are not short-lived. They remain constant, even under the most punishing service, throughout the life of the car. The precision adjustments built into this gear make it possible to restore the original accuracy of alignments and clearances, without difficulty.

ROSS *Cam and Lever* STEERING
ROLLER MOUNTED

ROSS GEAR & TOOL CO.
LAFAYETTE, INDIANA



Illustrating the

PINES AUTOMATIC BUILT-IN WINTERFRONT

. . . on WILLYS-KNIGHT 66-D

THERE is no uncertainty about the need and value of automatic motor protection. That is clearly brought out in the products of the WILLYS OVERLAND COMPANY. The Willys 66-D, illustrated above, is WINTERFRONT equipped at the factory. The Willys 8-80-D is so constructed that the AUTOMATIC WINTERFRONT can be readily installed in place of the radiator grill.

The Research and Engineering Departments of the PINES WINTERFRONT COMPANY are at your service. You are invited to consult with them when redesigning your radiators to provide the automatic motor protection which the public has a right to expect in your cars.

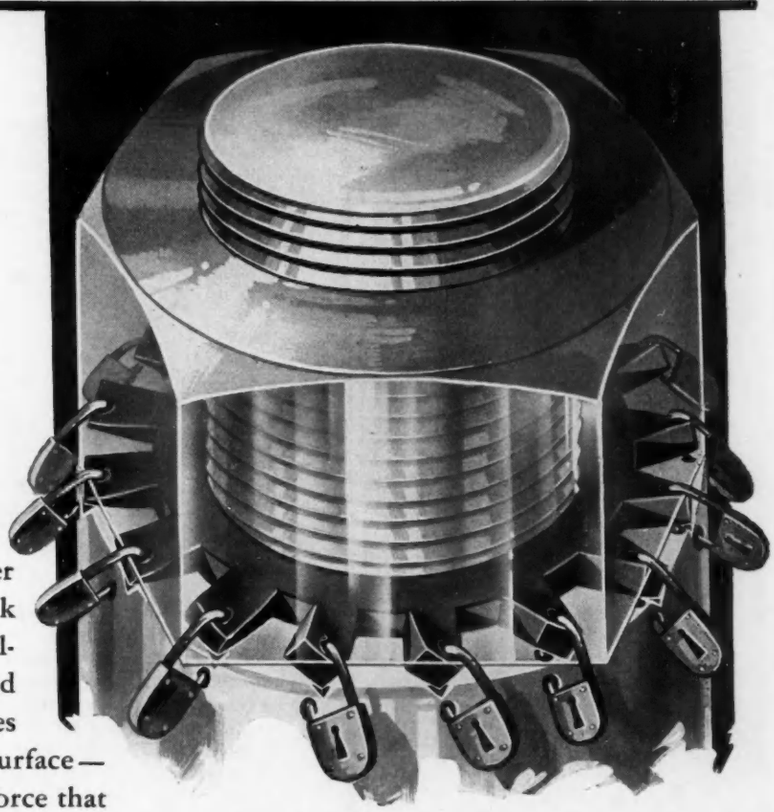
The entire line of Willys cars also offer as standard equipment: Pines Finger Tip Control, the combined starting, light and horn switch, conveniently operated from center of the steering wheel

PINES WINTERFRONT COMPANY
1129 N. Cicero Avenue,
Chicago, Illinois

Detroit Office:
2209-10 Fisher Building
Detroit, Michigan

SHAKEPROOF

Every *Twisted Tooth* Forms a *Separate Lock*

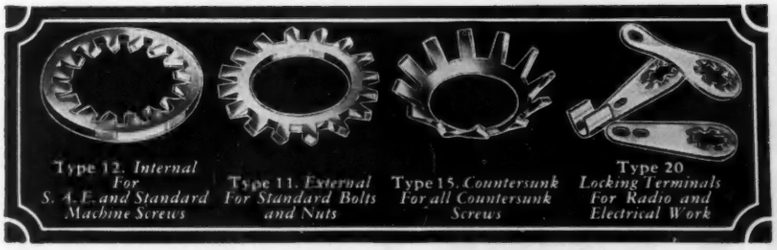


THE tremendous holding power of the Shakeproof Lock Washer is due to its patented multiple locking design. Each twisted tooth acts individually and bites into both the nut and work surface—setting up a powerful resisting force that positively prevents any movement of the nut. Then, realize that this force is multiplied from ten to sixteen times—depending on the number of teeth in the washer—and you can understand why Shakeproof is so far superior to any other locking method.

You can't save money by buying inferior lock washers. They are the greatest cause of poor performance, which means expensive service charges and dissatisfied customers. Give your product the benefit of Shakeproof protection—mail the coupon for trial samples, today!

U. S. Patents:
1,419,564
1,604,122
1,697,954
1,782,387
Other patents pending.
Foreign patents.

SHAKEPROOF
Lock Washer Company
{Division of Illinois Tool Works}
2507 N. Keeler Avenue, Chicago, Ill.


Type 12. Internal For S. A. E. and Standard Machine Screws
Type 11. External For Standard Bolts and Nuts
Type 15. Countersunk For all Countersunk Screws
Type 20 Locking Terminals For Radio and Electrical Work

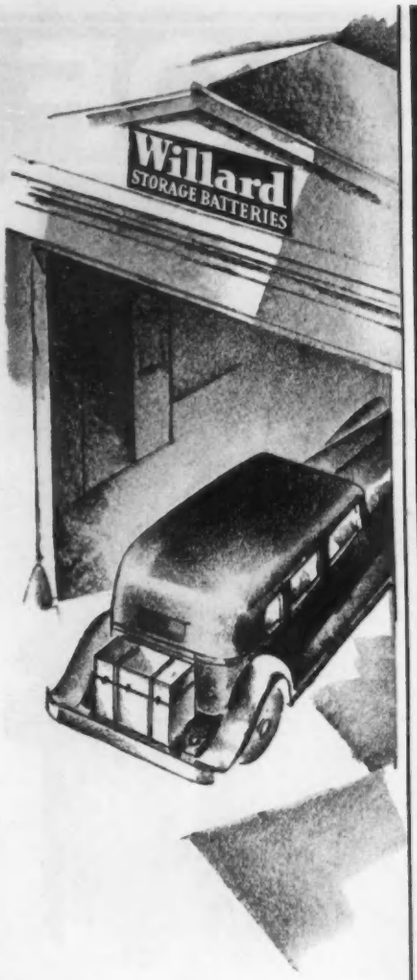
Shakeproof representatives are located in the following cities
New York City Philadelphia Boston Pittsburgh Schenectady Cleveland
Detroit Toledo Cincinnati Birmingham, Ala. Dallas, Texas Milwaukee
Los Angeles Seattle San Francisco Toronto, Ontario, Canada

COUPON

Gentlemen: We want to test your Shakeproof Lock Washers. Kindly send us samples as indicated.

Type..... Size.....
Type..... Size.....

Firm Name.....
Address.....
City.....*State*.....
By.....*Title*.....



Willard Thread-Rubber insulation is made of vulcanized rubber reinforced with hard rubber ribs. It unites the electrical insulating value and durability of rubber with the uniform porosity of cotton threads. You can get it only in a Willard. All Thread-Rubber batteries are in genuine hard rubber containers.

•

Willard wood insulation is made only from first grade and genuine Port Orford cedar, the finest insulating wood known for batteries. These separators are cut exclusively from selected growths, are chemically treated in a process controlled by Willard laboratories, and subjected to rigid tests and inspections before use.

"Built to serve well .. and kept fit by Nation-wide Service"..

Millions of car owners have found that Willards do their work dependably, and give *more* miles and months of satisfactory performance. Their experience is reflected in the fact that, year after year, they buy more Willards than any other make of battery.

The Willards they buy are soundly designed, ruggedly built, and sold in the correct electrical sizes to fit their particular makes and models of cars. And the convenient service facilities that Willard offers at 38,000 battery stations are their assurance not only of getting out of their batteries all that was built into them at the factory — but also of *keeping them fit* to perform dependably at all times. Car owners have learned that a battery kept in condition has much to do with the driving satisfaction they get out of their cars.

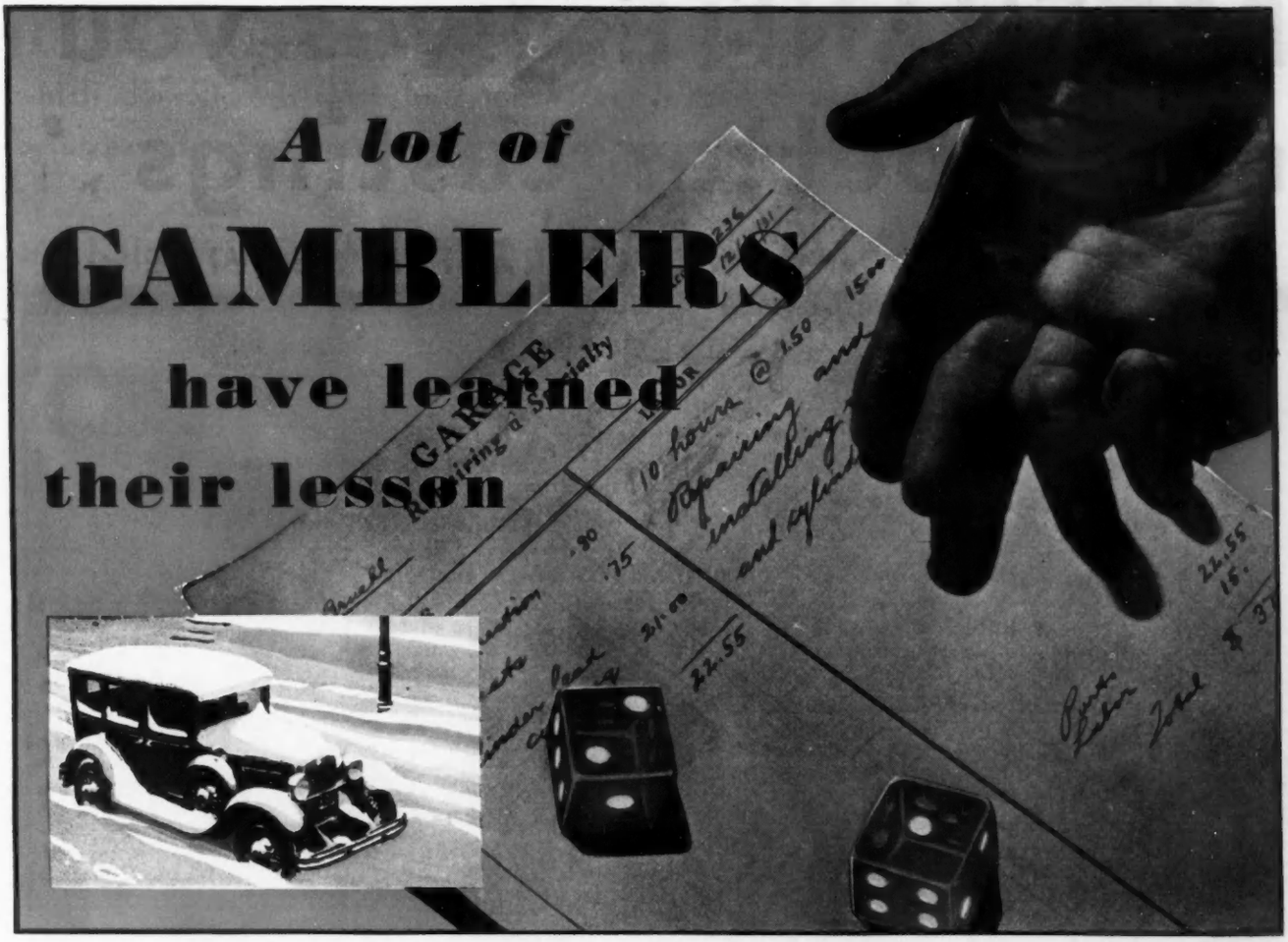
STORAGE BATTERIES

Willard

CLEVELAND·OHIO

LOS ANGELES·CALIF. · TORONTO·ONT.

DON'T GAMBLE WITH WEATHER···USE EVEREADY PRESTONE



A MILLION and a half car owners used Eveready Prestone last winter and went through the season without worry or repair bills. Meanwhile other motorists were gambling with makeshift anti-freeze mixtures—constantly testing and refilling their radiators, or forgetting to do so, and paying for repairs on frozen cars. A lot of those gamblers have learned their lesson. This year they will use Eveready Prestone—dependable through every change of weather.

Eveready Prestone, the first product scientifically developed for the single purpose of giving complete protection to cooling-systems, has now been further improved. It is to automotive engineers that this new product owes much of its success. They have put it to exhaustive tests and have proved that Eveready Prestone keeps water free-flowing at the lowest driving temperatures; that it will not evaporate in warm weather; that it now has even less tendency to leak than water; and that it definitely retards rust and prevents clogging. The new Eveready Prestone is generally accepted by automobile manufacturers.

A good car is worthy of good treatment. And cars will run better, stand up better, look better, when safe, sure Eveready Prestone is their winter protection.

NATIONAL CARBON CO., INC.
General Offices: New York, N. Y.
Unit of Union Carbide UCC *and Carbon Corporation*

9 POINTS OF SUPERIORITY

1. Gives complete protection.
2. Does not boil off.
3. Positively will not damage cooling-system.
4. Will not heat up a motor.
5. Circulates freely at the lowest operating temperatures.
6. Will not affect paint, varnish or lacquer finishes.
7. Non-inflammable and odorless.
8. Prevents formation of rust in cooling-system.
9. Economical — one filling lasts all winter.

EVEREADY PRESTONE

MEEHANITE gives you much better castings.

COMPARATIVE SERVICE

	Part	Type of Service
1	Beaters	Coal Pulverizer
2	Blow Pipes	To Tuyeres of sheet mill heating furnace
3	Chute	Handling hot clinker (1100° F.) cement kiln
4	Crusher Rolls	Crushing bank run gravel
5	Crusher Rolls, corrugated	High Speed Rock Crusher
6	Dies	Hammer Bed
7	Dies	Forging Railroad Spikes
8	Fan Impellers	Handling corrosive gases
9	Flange Bolts	Pipe line carrying acid solution
10	Gears	Driving mine machinery
11	Impellers	Sub-aeration type flotation machine acid circuit
12	Pinions	Driving a 7′ x 6′ Ball Mill in a foundry
13	Pump Parts	Contact Sulphuric Acid plant handling 93-98% acid
14	Retorts 8′ x 12″ Dia.	Beet Sugar Refinery
15	Rolls	Rolling 3/16″ shovel points at cherry red heat
16	Scroll Sheets	Blast fan in cotton gin
17	Skid Castings	Sheet Mill Heating Furnace
18	Stoker Grates	Power Boiler
19	Wear Plates	Ore Washing Machinery

METAL

Call the nearest Meehanite foundry for engineering data on what can be accomplished with your castings.

PHYSICAL PROPERTIES

Castings made under the Meehanite Process are superior to other irons. They have:
Greater Strength and Toughness.
More uniform grain Structure and Hardness.
Greater Resistance to Abrasion.
Greater Density.
Higher Resistance to Corrosion.
Freedom from spongy regions regardless of casting section.
Better Machinability.

Specific properties obtainable on specification:
Tensile Strengths to 50,000 lbs. without heat treatment.
Tensile Strengths to 70,000 lbs. with heat treatment.
Brinell Hardness up to 600 by heat treatment.
Six times the impact strength of semi-steel.

Here are a few typical cases which demonstrate just how much is being saved by the use of Meehanite on equipment in which castings are subjected to severe stresses, hard wear, excessive heat and corrosion.

MEEHANITE WITH OTHER METALS

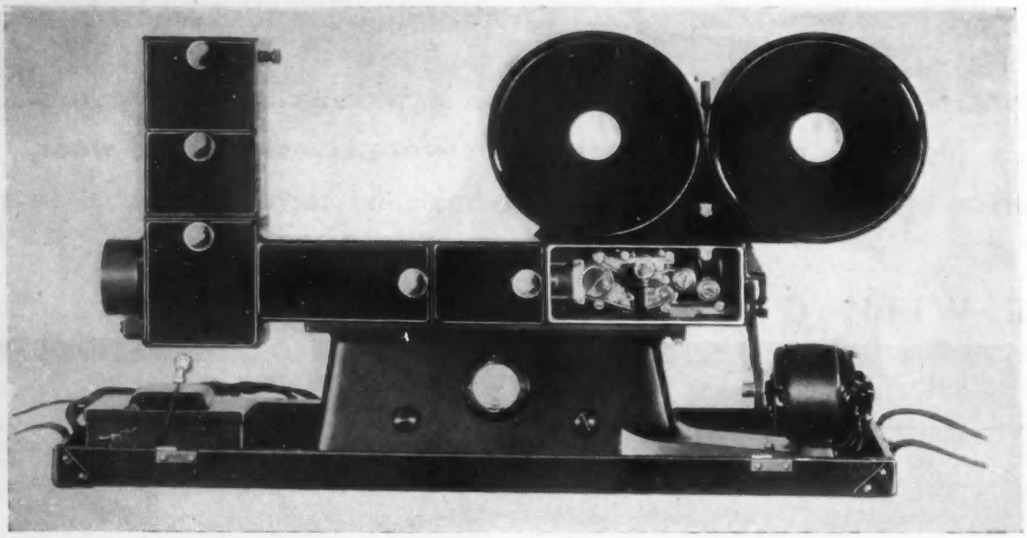
As Originally Made		Made of Meehanite		
Metal Used	Av. Operating Life	Av. Operating Life	% Increase	
Mang. Steel	3 weeks with 50% drop in efficiency	3 months with 25% drop in efficiency	333	1
Cast Iron	10 days	3 months	800	2
Cast Iron	3 months	6 months	100	3
Mang. Steel	Less than 4 weeks	12 weeks	200	4
Mang. Steel	80,000 tons	120,000 tons	50	5
Nickel Chromium Steel	3 months	18 months	500	6
Semi-Steel	100 kegs	500 kegs	400	7
Antimony and Lead	5 weeks at 425 r. p. m.	12 months at 625 r. p. m.	940	8
Steel	20 days	7 months	950	9
Steel	12 weeks	15 months	442	10
Cast Iron	4 weeks	8 weeks	100	11
Semi-Steel	10 days	102 days	920	12
Cast Iron and Steel	40 days	5 months	275	13
Cast Iron	18 months	2 years—still in good condition	33	14
Chilled Iron	18 months	5 years	233	15
Cast Iron	1500 bales	2250 bales	50	16
Cast Iron White Iron	30 days 60 days	9 months 9 months	800 350	17
Cast Iron	40 days	60 days with increase of 500° in temperature	50	18
Steel	30 days	100 days	233	19

Meehanite Patents: U. S. Patent Nos.: 1,449,068 » 1,683,087 » 1,683,086 » 1,731,346. Canadian Patent Nos.: 234,933 » 287,903 » 304,254. Other patents pending.

MEEHANITE INSTITUTE

MEEHANITE FOUNDRIES

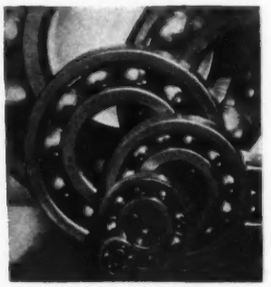
ANSONIA, CONN. . . . . Farrel Birmingham Co.
CHATTANOOGA, TENN. . . . . Ross-Meehan Foundries
CHICAGO, ILL. . . . . Greenlee Foundry Co.
CLEVELAND, OHIO . . . . . Fulton Foundry & Machine Co.
DETROIT, MICH. . . . . Michigan Valve & Foundry Co.
INDIANAPOLIS, IND. . . . . Indianapolis Casting Co.
PHILADELPHIA, PA. . . . . H. W. Butterworth & Sons Co.
PITTSBURGH, PA. . . . . Rosedale Foundry & Machine Co.
ST. LOUIS, MO. . . . . Banner Iron Works
TRENTON, N. J. . . . . Trenton Malleable Iron Works
TORONTO, ONT. . . . . Dodge Manufacturing Co.
TORONTO, ONT. . . . . Jessop Steel Company



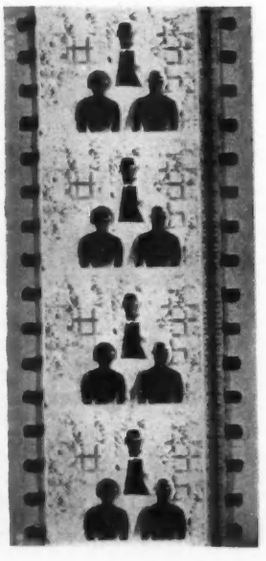
1734

Playing a silent part in the talkies

New Departures are Hollywood bound. Like good actors they have been chosen for their ability in playing their part well. Look sharply at the film below and you will see a dark wavy streak just to the right of the pictures. This is the sound track. The mechanism above transforms sound into this grotesque shape and registers it accurately on the film. Let Electrotone engineers tell you why 15 New Departure Ball Bearings are used in its construction. "Inasmuch as the film on which the image of the sound is photographed must not be permitted to deviate in the least, as this would produce a distorted sound track, it was, therefore, paramount that dependable and precision bearings of the highest quality be used. This was accomplished through the medium of New Departure Ball Bearings, which we find answer our purpose to the fullest extent." When 4,500 eager men and women set out to do a fine piece of work, they simply cannot be stopped. New Departure quality has such a human foundation. The New Departure Manufacturing Company, Bristol, Connecticut; Detroit, Chicago, San Francisco.



Electrotone Sound on Film Recording System is a product of the Electrotone Corp., Gratiot Ave., at Racine, Detroit, Mich.



NEW DEPARTURE BALL BEARINGS

SAFETY IN THE MAKING

From the drawing board to its final mounting on the chassis, the Bendix-Westinghouse compressor is ever a source of pride to those responsible for its development and manufacture ★ This sturdy unit, the heart of the Air Brake, is designed to more than meet the most rigid requirements of actual service ★ Each step in its production is constantly guarded with the same precise care you would expect of the watchmaker ★ Inspections . . . no end, and an actual operating test round out its program ★ How well the Bendix-Westinghouse Compressor merits the extreme care which attends its manufacture is best written in its years of never-failing service as a part of the braking system which safeguards the world's most prominent, heavy duty highway transport vehicles ★ Should you desire more specific information regarding the history making dependability of this remarkable unit, merely address the BENDIX-WESTINGHOUSE AUTOMOTIVE AIR BRAKE COMPANY at Pittsburgh, Pennsylvania.

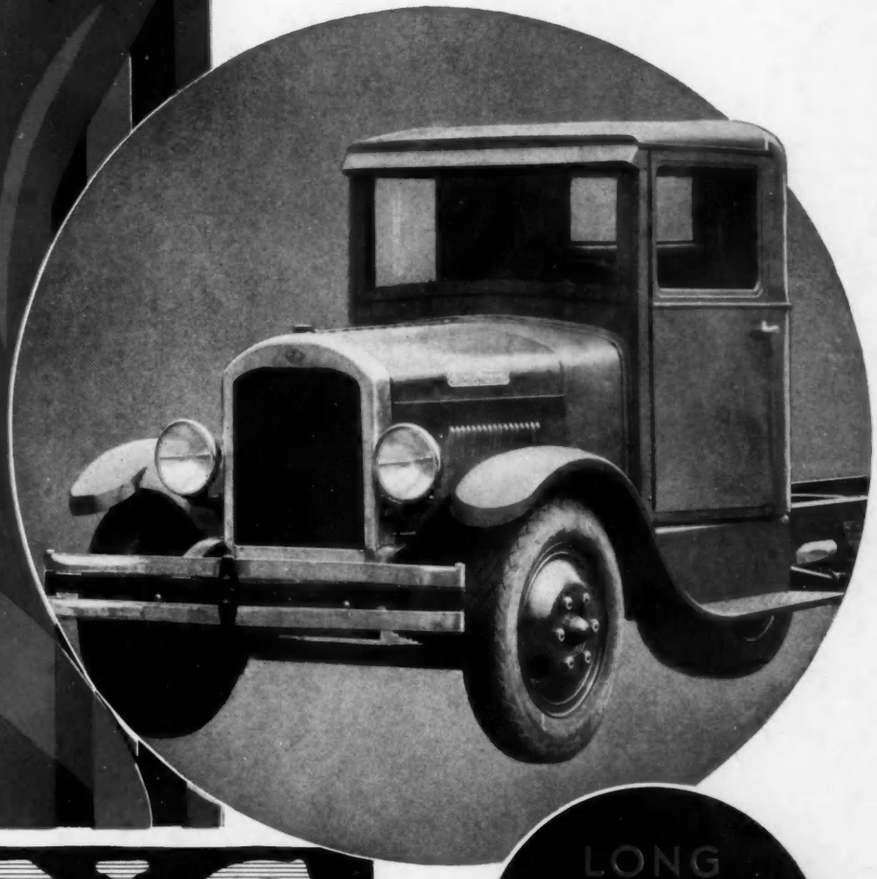
6289

BENDIX WESTINGHOUSE

AUTOMOTIVE AIR BRAKES

9
Motor Wheel
WOOD-WIRE-STEEL-Interchangeable on One Hub
MOTOR WHEEL CORPORATION · LANSING, MICHIGAN

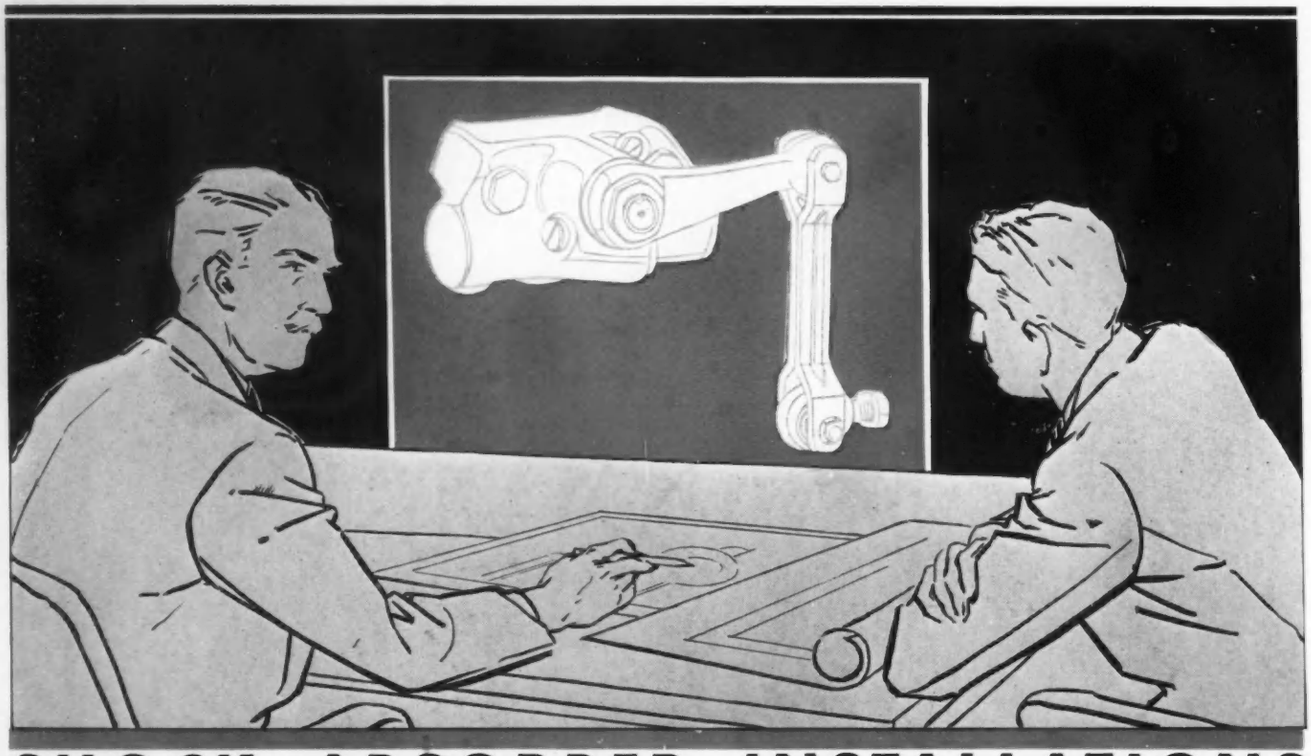
THE COMPLETE LINE OF FISHER-STANDARD TRUCKS IS EQUIPPED WITH LONG RADIATORS



LONG

LONG PRODUCTS
AUTOMOTIVE
CLUTCHES AND
RADIATORS

LONG MANUFACTURING CO., DETROIT, MICHIGAN
DIVISION OF BORG-WARNER CORP.



SHOCK ABSORBER INSTALLATIONS SHOULD BE CONSIDERED WHEN THE CAR IS PLANNED . . . .

To insure maximum riding comfort in your next car model, plan the shock absorbers as an integral part of the chassis. Call in a Delco engineer early. Let him help you determine the proper location for the hydraulic shock absorbers—let him co-operate with you in designing an installation that will be easy to assemble, and readily accessible for making adjustments. Delco engineers bring you full advantage of their broad experience in designing shock absorber systems for all classes of service. They will help you achieve the kind of riding comfort that sells cars.

Delco

DUODRAULIC

SHOCK ABSORBERS

DELCO PRODUCTS CORPORATION, DAYTON, OHIO

DO NOT IGNORE THESE TWO *Common sense precautions*

STOP

when the traffic light is red

. . . *demand* SAFETY GLASS *in your new car*

Common Sense has dictated every safety measure in traffic regulation and motor car manufacture that has been effected within the last ten years. This is the period of refinement in automobile manufacture. The next major improvement—one that even now has gained the endorsement of more than half the automobile manufacturers in the country—will be the adoption of safety glass as complete equipment by all manufacturers.

This obvious means of eliminating the greatest remaining danger in motoring—that of broken, flying glass—is one that engineers must consider.

Floyd Gibbons' famous Safety Crusade is sweeping the country. Based on pure common sense which decrees that shatterproof glass is essential to safety, the public demand is becoming universal—and within a very short time Safety Glass must be included as standard equipment in all new cars. One of the most serious problems confronting the manufacturer today is the trade-in value of his product. A car equipped with Safety Glass will have a materially increased re-sale value.

Libbey • Owens • Ford Safety Glass is made by an exclusive process, which produces a glass of remarkable clarity and strength, besides the priceless protection which it affords the motorist. The edges of L • O • F Safety Glass are sealed against moisture, heat and other elements, increasing the life and strength materially, and preserving the clarity of vision. L • O • F Safety Glass is used by more automobile manufacturers than any other laminated glass on the market.

Packard and Graham; Studebaker, Franklin, Reo, Willys and Willys-Knight cars; the fine custom bodies of Dietrich and LeBaron; Reo Speed Wagons, Twin Coaches, Brill Trolley Buses, Cincinnati Trackless Trolley Coaches, Bender Bus Bodies, Hackney and Springfield School Buses, Stinson Aircraft, Gar Wood and Matthews in the marine field—all are users of L•O•F Safety Glass.

LIBBEY • OWENS • FORD GLASS COMPANY
TOLEDO, OHIO

Manufacturers of Polished Plate Glass, Flat Drawn Clear Sheet Glass for windows, and Shatterproof Safety Glass; also distributors of Figured and Wire Glass manufactured by the Blue Ridge Glass Corporation of Kingsport, Tenn.

LIBBEY • OWENS • FORD
SAFETY GLASS

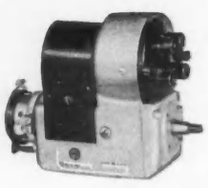
AMERICAN BOSCH SALES & SERVICE

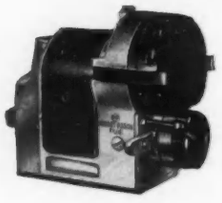
BOSCH ROBERT BOSCH A.G. SALES & SERVICE

Products of American Bosch

Products of Robert Bosch, A.G.

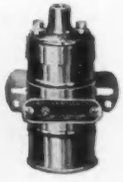
The American Bosch Magneto has successfully served all types of engine owners year after year. Weatherproof, trouble-proof performance on all types of engines.





The Bosch Super-Energy Magneto meets the exacting demands of all kinds of service. Waterproof and thoroughly efficient on all types of engines.

American Bosch Coil is an electrical unit of outstanding design and construction. It is built for long life service on high speed —high compression engines. The coil is waterproof, oil proof and weather proof.



The Bosch Pyro-Action Spark Plug is provided in all types and sizes to meet the demands of the modern motor for heavy duty or speed service.

The American Bosch Motor Car Radio is complete with receiver, station selector, five tubes, special "B" batteries, battery box, cone speaker, antenna and all required shielded cables, ready to install.

The Bosch Vibro-Balanced Horn revolutionized the horn market. There is a Bosch Horn for every purse and purpose.

American Bosch Motor Boat Radio is a five tube receiver in two models, one for runabouts, the other for cabin type cruisers. Both are built for heavy duty service—and all material has been treated to resist the effects of moisture and air.

The Bosch Semaphore gives a new standard of motoring safety day and night. The Bosch Semaphore has one arm for each side of the car, electrically operated. It improves the appearance of any car.

EACH of the products illustrated on this page has long been recognized for its dependability by the American public, and each is supreme in its field for service and satisfaction. Each is a profit builder and each is a reputation builder for you.

Step up your sales and pep up your salesmen with these famous Bosch and American Bosch products.

The Bosch electric windshield wiper is powerful, quiet, and uses very little current. It is very compact, being only 5" long by 2¾" in diameter. Finished in black enamel with nickeled switch lever.

PRODUCTS OF AMERICAN BOSCH MANUFACTURED BY—

PRODUCTS OF ROBERT BOSCH, A. G., STUTTGART, GERMANY SOLD BY—

UNITED AMERICAN BOSCH CORPORATION

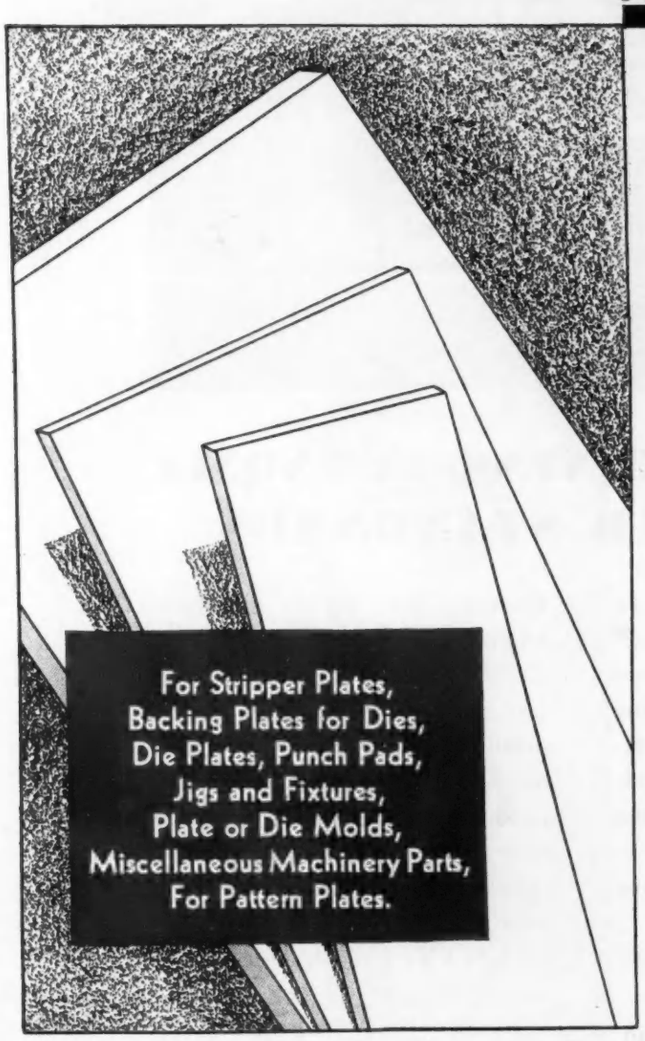
SPRINGFIELD MASSACHUSETTS

ADAPTABILITY WITH ECONOMY

J&L STEEL COLD FINISHED

WIDE COLD ROLLED FLATS

TRUE TO SIZE
TRUE TO SECTION
BRIGHT FINISH



For Stripper Plates,
Backing Plates for Dies,
Die Plates, Punch Pads,
Jigs and Fixtures,
Plate or Die Molds,
Miscellaneous Machinery Parts,
For Pattern Plates.

AVAILABLE in widths up to 12" and thicknesses up to 2½", J & L Wide Cold Rolled Flats offer an adaptability that makes possible worth-while savings.

Made to exacting J & L standards, under J & L ownership-control of all raw materials and processes of manufacture from ore to finished product, J & L Wide Cold Rolled Flats are bright in finish, accurate to size, and true to section. They are suited to a wide variety of applications. Frequently they may be used economically to replace forgings, expensive castings, or hot rolled plates which would have to be planed to size.

Like all J & L products, J & L Wide Cold Rolled Flats have the uniformity, the maintained quality, the consistent excellence that have made the J & L mark a promise of complete customer satisfaction.

J&L STEEL

JONES & LAUGHLIN STEEL CORPORATION

AMERICAN IRON AND STEEL WORKS

JONES & LAUGHLIN BUILDING, PITTSBURGH, PENNSYLVANIA

Sales Offices: Atlanta Boston Buffalo Chicago Cincinnati Cleveland Dallas Denver Detroit Erie Los Angeles Memphis Milwaukee Minneapolis New York Philadelphia Pittsburgh St. Louis San Francisco Washington

Warehouses: CHICAGO CINCINNATI DETROIT MEMPHIS NEW ORLEANS PITTSBURGH

Canadian Representatives: JONES & LAUGHLIN STEEL PRODUCTS COMPANY, Pittsburgh, Pa., U. S. A., and Toronto, Ont., Canada

MACK TRUCKS, INC.

Another prominent user of **SKF** *Bearings in the Automotive Industry*

Where PERFORMANCE TAKES PREFERENCE over PRICE

SKF RUGGEDNESS, ECONOMY MEET MACK STANDARDS

IN the thickest traffic . . . or out on the open road... SKF Ball Bearings on modern buses are ever ready with unfailing service to meet the varying demands of daily transportation. Smooth operation, ruggedness and a long life with little watching are all-important to low cost operation.

On this Mack Bus, SKF Bearings live up to all these expectations continuously. SKF's are used on the pump, fan, generator, magneto, clutch pilot, clutch throwout, transmission and rear axle pinion mounting. On this job, thru the rigors of long distance, high-safe-speed service, SKF's do their part to insure the utmost PERFORMANCE with economy.

SKF INDUSTRIES, INC., 40 East 34th Street, New York, N. Y.

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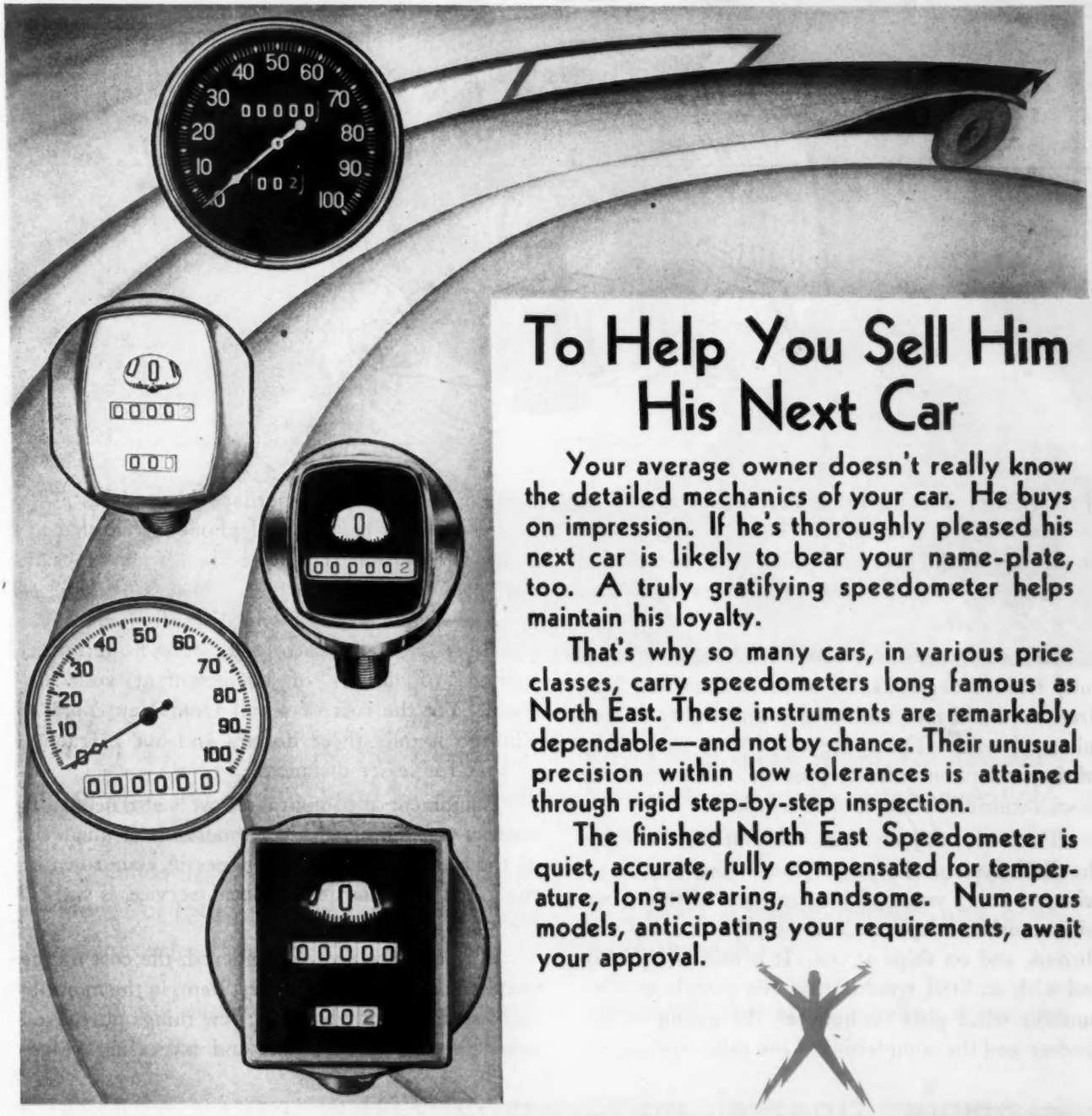
SKF

NORTH EAST

S · P · E · E · D · O · M · E · T · E · R · S



To Help You Sell Him His Next Car

Your average owner doesn't really know the detailed mechanics of your car. He buys on impression. If he's thoroughly pleased his next car is likely to bear your name-plate, too. A truly gratifying speedometer helps maintain his loyalty.

That's why so many cars, in various price classes, carry speedometers long famous as North East. These instruments are remarkably dependable—and not by chance. Their unusual precision within low tolerances is attained through rigid step-by-step inspection.

The finished North East Speedometer is quiet, accurate, fully compensated for temperature, long-wearing, handsome. Numerous models, anticipating your requirements, await your approval.

DELCO APPLIANCE CORPORATION

ROCHESTER, N.Y., U.S.A.

STARTERS • GENERATORS • IGNITION • HEATERS • SPEEDOMETERS

THE UNSEEN

COURIERS

OF THE SPOKEN WORD

THE FAMILIAR TELEPHONE that stands upon your desk at the office or in your home is only a very small part of the great communication system that enables you to talk across the miles with such surprising ease.

Behind it are complicated exchanges, a carefully trained organization of more than four hundred thousand men and women and eighty million miles of wire. These are the forces that make efficient telephone service possible. These are the unseen couriers of the spoken word.

Tirelessly, day or night, without rest or sleep, the Bell System awaits but the lifting of the receiver to carry your voice to any one of thirty-two million other telephone users in this country and abroad, and on ships at sea. It is done so quickly and with so little trouble that few people stop to consider what goes on between the giving of the number and the completion of the call.

Some time every day—perhaps many times a day—you use some part of a telephone system that has taken fifty years and more than four thousand million dollars to build.

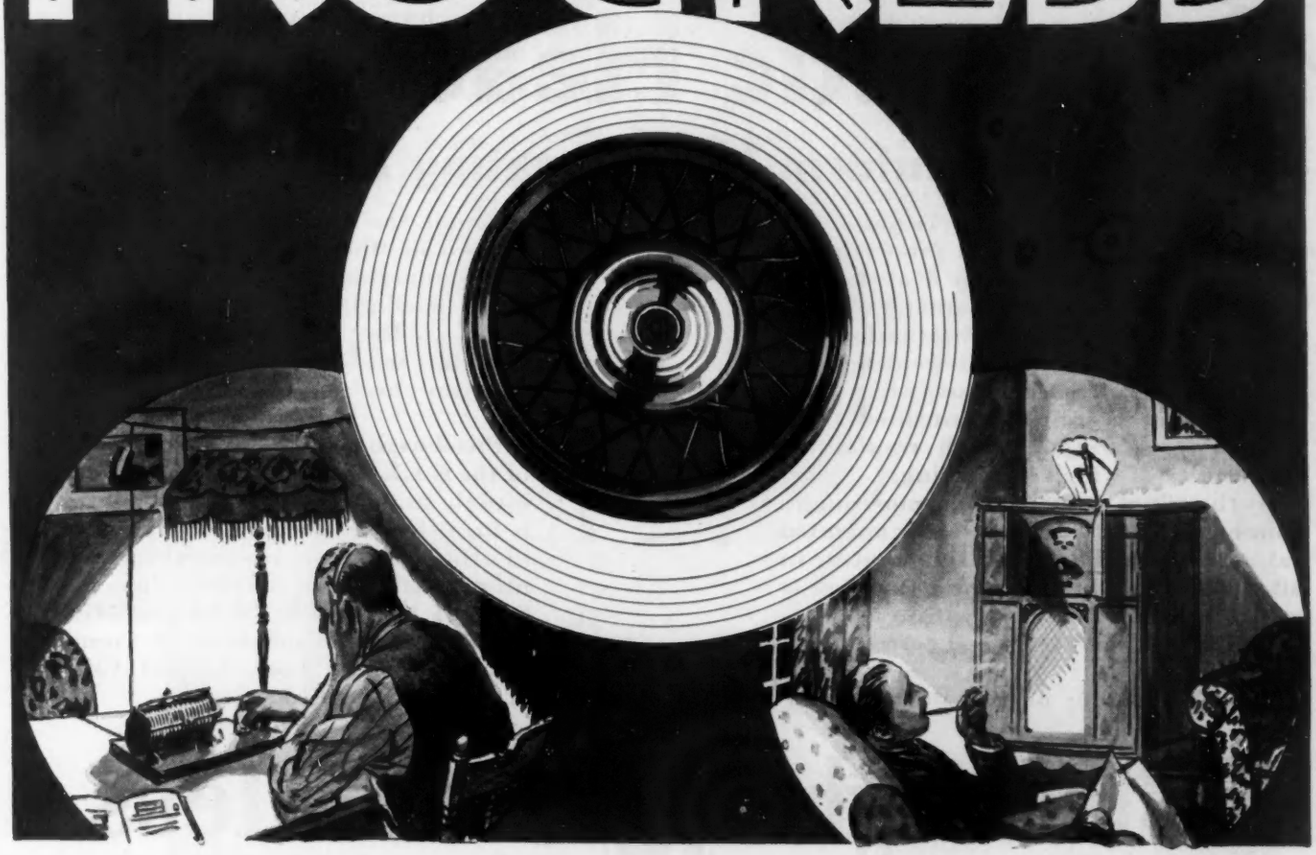
The simple words "long distance," which you speak so casually into your telephone, place millions of dollars of equipment at your disposal. Yet the cost of a call from New York to Chicago is only three dollars and but a fraction of that for lesser distances.

Equipment of comparable cost is also needed to connect your home with the thousands or hundreds of thousands of other telephones in your town or city. Yet the charge for local service is only a few cents a day.

In relation to service rendered, the cost of the telephone is one of the smallest items in the monthly business and family budget. Few things purchased are of such real, constant and increasing value.

★ *AMERICAN TELEPHONE AND TELEGRAPH COMPANY* ★

PROGRESS



IN THE transition from the old Radio "head-set"—which in its day was a marvel indeed—to the magnificent, exquisitely toned cabinet model of today, a tremendous scientific advance has been made.

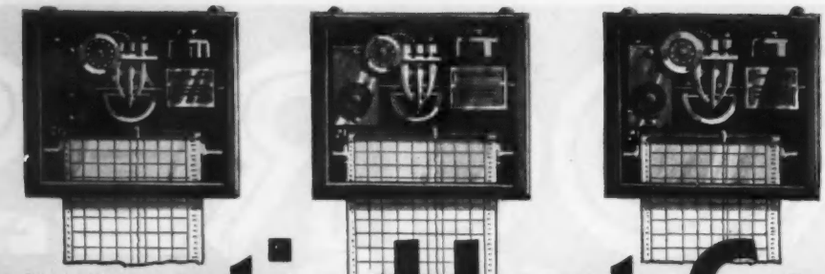
As highly significant progress has been made in the development of the Kelsey-Hayes steel spoke wheel. For now each Kelsey-Hayes spoke is an ever-tight, permanent part of the wheel. Tension is equalized in all directions resulting in perfect wheel alignment and enormous strength.

Kelsey-Hayes steel spokes need no adjustment.

KELSEY-HAYES WHEEL CORPORATION, DETROIT, MICHIGAN

KELSEY-HAYES

WOOD · WIRE · DISC · WHEELS



Automatic Heat Control

For Uniform Heat-Treating Results

The trend is to alloy steels. To obtain the full advantages in physical properties alloy steels must be correctly heat-treated. Because of the sensitive character of these steels, relatively slight fluctuations in temperature during heat-treating give widely varying results. But, when temperatures are carefully controlled these alloyed steels respond with results the uniformity of which is amazing.

By the use of numerous thermo-couples connected directly to electrically operated valves on the fuel lines, the temperature in all parts of our heat-treating furnaces is controlled automatically within 5° Fahrenheit of the predetermined correct temperature.

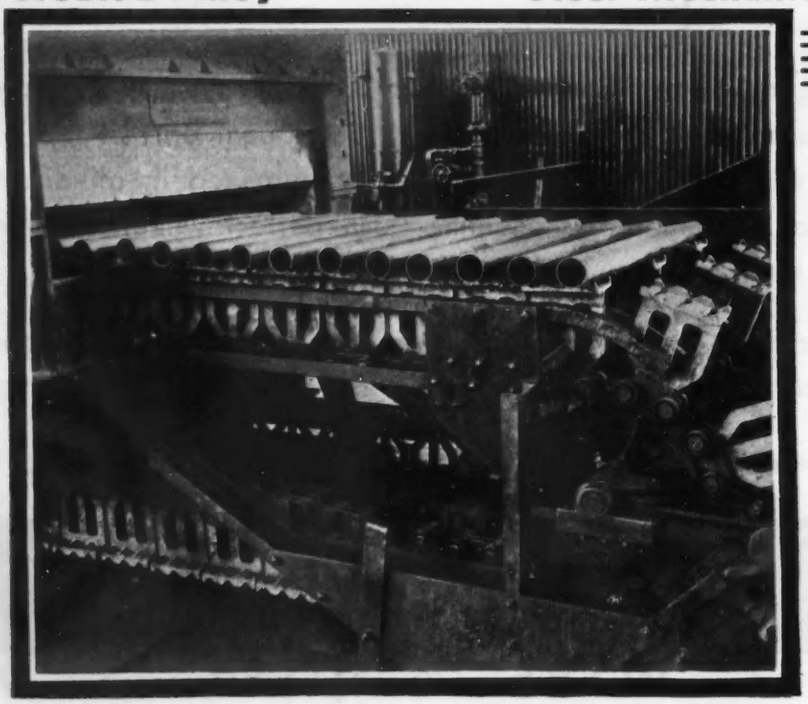
Also the timing of the work passing through the furnace and the temperatures and other conditions of quenching and tempering are controlled automatically to eliminate the factor of human error . . . The uniformity of Pittsburgh Seamless heat-treated tubes is such that you can check one piece and accept the lot.

Pittsburgh Seamless is available in most of the S.A.E. Series containing chromium, nickel, molybdenum and vanadium. It is furnished flanged, upset, expanded and in other special shapes requiring a minimum of machining and finishing. PITTSBURGH STEEL PRODUCTS COMPANY, Division of Pittsburgh Steel Company, Pittsburgh, New York, Detroit, Chicago, St. Louis, Tulsa, Houston.

Division of Pittsburgh Steel Co.

Pittsburgh P Seamless

Heat-Treated Alloy Steel Mechanical Tubing



The Firestone STANDARDIZED 28° BEVEL does 3 things!

1. Permits a changeover to any other rim size you may require.
2. Assures positive alignment with ease of application.
3. Provides proper spacing for all tire sizes.

The rim base itself is a one-piece unit and is never disturbed when changing tires.

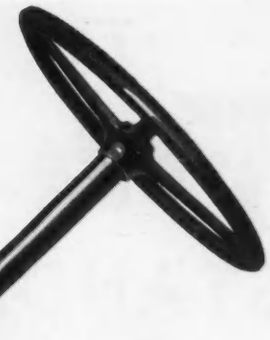
Firestone

CONTINUOUS BASE RIMS

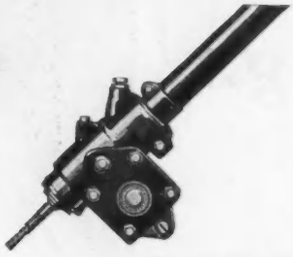
FOR ALL TYPES OF WHEELS—WIRE, WOOD, DISC AND CAST

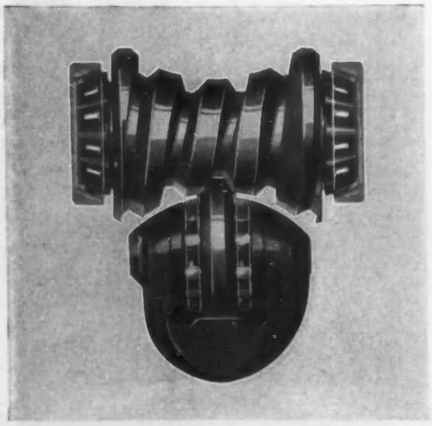
Copyright—1931—The Firestone Steel Products Company.

All Cars Look Alike at This End

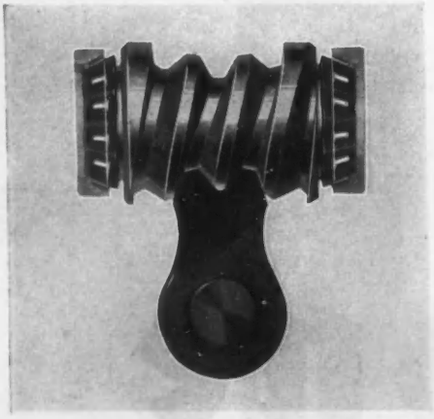


. . . But the Difference in Performance Lies *Here*





Gemmer worm-and-roller steering brings brilliant steering ease to the heaviest cars



Worm-and-sector steering, for lighter cars brings to them the utmost in steering performance

ON most cars steering wheels are practically the same. Steering columns and tie rods are also similar. But the vast difference in steering performance of any two cars lies in the steering gear. And prospects instantly notice the difference in the steering ease of cars.

Cars equipped with Gemmer worm-and-sector or Gemmer worm-and-roller steering gears are more comfortable to drive. That is why fully eighty five per cent of the cars on the road today are equipped with steering of one of these types. Manufacturers recognize the quality which has made Gemmer the leading manufacturer of steering gears.

GEMMER

MANUFACTURING COMPANY . . . DETROIT

SMOOTHER STEERED WHEN GEMMER GEARED

"IT'S A CINCH

to machine CARPENTER STAINLESS No. 5"

That's the story we get from the maker of these washing machine shafts. "Machines as easily as Cold Rolled Steel," he says.

When we first perfected Carpenter Stainless No. 5 and boldly came forward with the statement that it could be machined, ground, or polished as readily as ordinary screw stock, there was much skepticism . . . but many "show-me-trials". And these trials brought amazing results. One after another, manufacturers told us that No. 5 went through the machining and grinding operations without a bit of difficulty, without loss of speed or change of set-up.

And today, after three years of leadership, Carpenter No. 5 still carries the field on performance. It has enabled scores of manufacturers to adopt stainless with all its manifest advantages, and to do this at a minimum increase in cost.

Carpenter Stainless No. 5 has proven itself so many times that we welcome the opportunity to furnish samples for trial on the most difficult machining jobs. Just write us.

THE CARPENTER STEEL CO.
107 W. Bern Street, Reading, Pa.

Licensed under patents of the American Stainless Steel Company.

Carpenter STAINLESS STEEL *No.* 5

1. **BLANKING**
2. **A SINGLE DRAW**
   (*and a deep one, too*)
3. **BUFFING**
   (*after being attached to the base*)

. . . AND THE RESULT . . .

A *Brilliant Finish that is* PERMANENT

. . . Without Polishing or Plating Operations

These brilliant Bumper Medallions are made from Carpenter Stainless (14% chromium) Strip Steel . . . proving that deep draws are possible . . . that economical production is possible . . . when the *right* stainless is used.

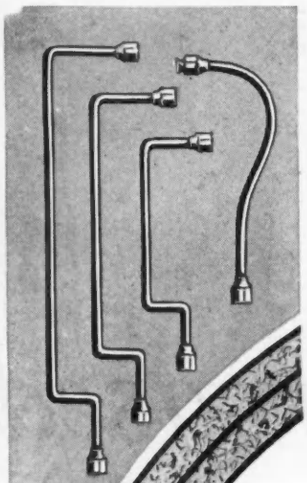
On this job, Carpenter Stainless Strip came through the drawing operation with a surface so smooth, that only buffing was necessary to impart a permanently brilliant finish that outrivals any plating.

This is only one of many instances where Carpenter Stainless Strip (in either 14% chromium or 18-8 chrome-nickel grades) has accomplished results that had been considered impossible for a stainless steel.

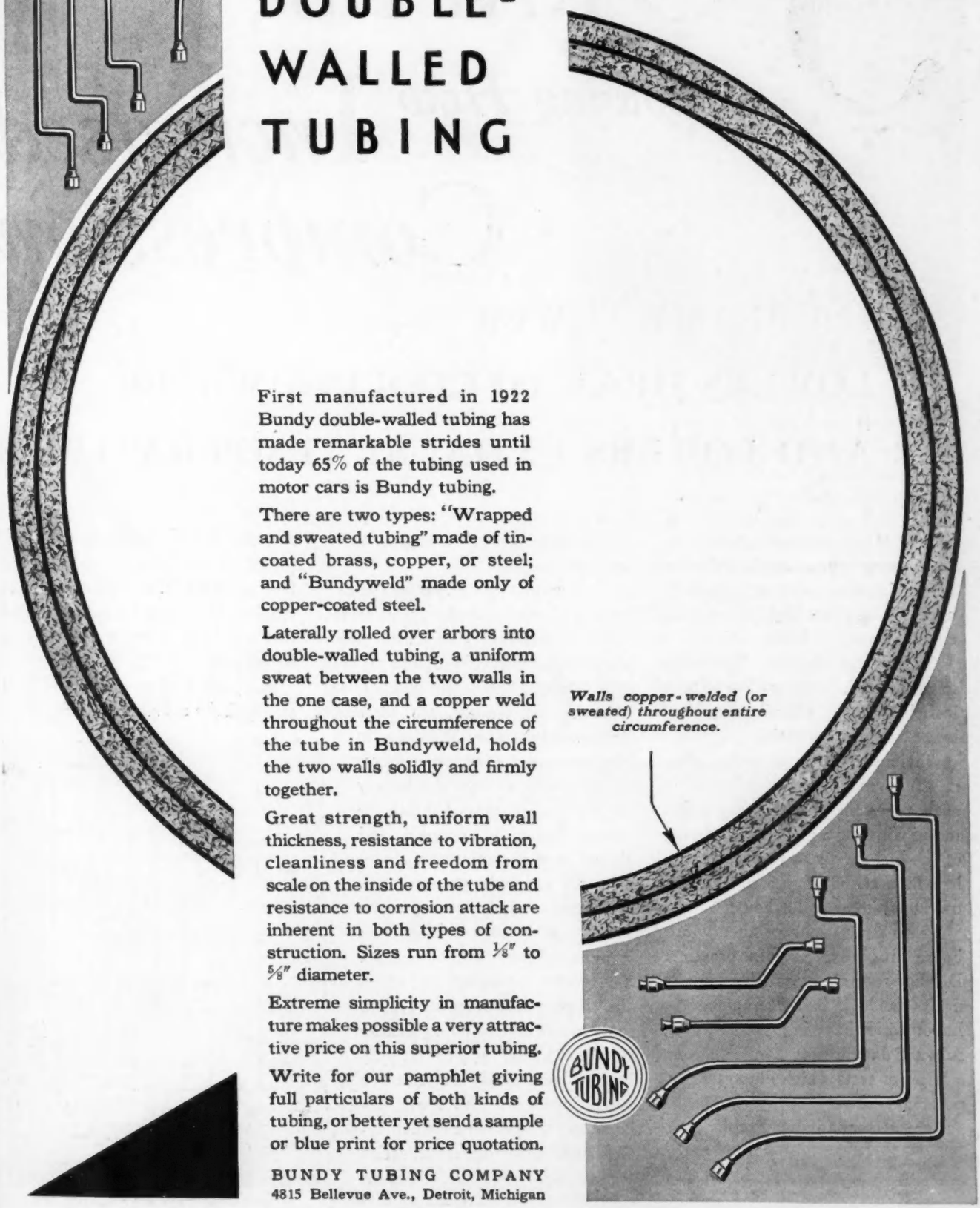
No matter how difficult the job you want to put up to "stainless", don't decide it's "impossible" until you've tried Carpenter Stainless. We'll gladly supply samples in the right grade, if you will tell us your requirements.

THE CARPENTER STEEL COMPANY
107 W. Bern Street, Reading, Pa.
Tool and Alloy Steels Exclusively

Carpenter
STAINLESS STEEL *Stri*



BUNDY SOLID DOUBLE-WALLED TUBING



First manufactured in 1922 Bundy double-walled tubing has made remarkable strides until today 65% of the tubing used in motor cars is Bundy tubing.

There are two types: "Wrapped and sweated tubing" made of tin-coated brass, copper, or steel; and "Bundyweld" made only of copper-coated steel.

Laterally rolled over arbors into double-walled tubing, a uniform sweat between the two walls in the one case, and a copper weld throughout the circumference of the tube in Bundyweld, holds the two walls solidly and firmly together.

Great strength, uniform wall thickness, resistance to vibration, cleanliness and freedom from scale on the inside of the tube and resistance to corrosion attack are inherent in both types of construction. Sizes run from 1/8" to 5/8" diameter.

Extreme simplicity in manufacture makes possible a very attractive price on this superior tubing.

Write for our pamphlet giving full particulars of both kinds of tubing, or better yet send a sample or blue print for price quotation.

BUNDY TUBING COMPANY
4815 Bellevue Ave., Detroit, Michigan

3 GRAPHS *Showing How Increased Compression*

. . . INCREASES POWER

. . . LOWERS HEAT TO COOLING WATER

. . . AND LOWERS EXHAUST TEMPERATURES

BECAUSE pressure raises the temperature inside cylinders before ignition, it is a commonly accepted idea that high compression engines present a heat problem.

Such is not the case. The waste heat of a high compression engine is less than that of a similar engine of lower compression ratio.

Obviously this is so, since when an equal amount of fuel is burned in each type, the higher compression motor converts a greater percentage of the fuel energy to power, leaving less heat to be dissipated through cooling systems and exhaust.*

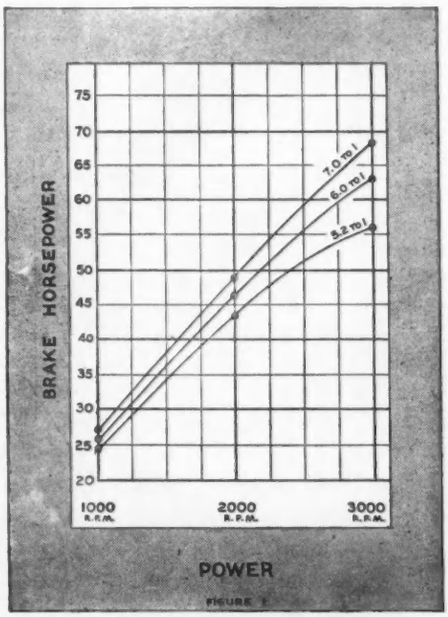
These conclusions of theory are borne out by experimental practice. During several years the experiments made in Ethyl Engineering Laboratories have indicated this result, and data are now available from a series of tests which illustrate the point conclusively.

The accompanying graphs are made from tests of a typical eight cylinder engine.

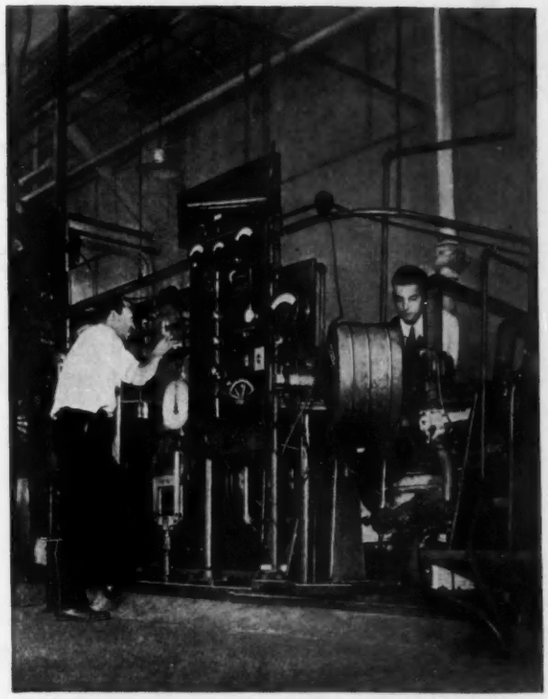
In Figure 1 the power of the engine is plotted with the use of three different heads to give compression ratios of 5.2 to 1, 6.0 to 1, and 7.0 to 1 (having compression pressures of 104 pounds, 130 pounds, 171 pounds, respectively). The differences in the percentage of power increases at different speeds are due largely to the use of planed heads to secure higher compression and do not exist if combustion chambers are correctly proportioned.

Figures 2 and 3 present the lower heat losses resulting from a more efficient use of energy. The cooler temperatures which the higher compression ratios maintain at given r.p.m. (because of their higher power output) become increasingly important as speed increases. The lower exhaust gas temperatures which accompany high compression ratios are of importance both because of the lower temperatures imposed on the exhaust valves and because of the smaller amount of heat transmitted from the exhaust pipe to the driving compartment during hot weather.

Body-designing engineers will also find the curves in Figure 3 par-



*This assumes the use of fuel of sufficient anti-knock value to prevent detonation in each engine.



In this heat balance experiment, the temperature of exhaust gases is measured by a thermocouple pyrometer. The amount of heat absorbed by cooling water is measured by sensitive thermometers which indicate the temperature of the water upon entering and leaving the cooling jacket, and by scales which weigh the amount of water passing through. The torque is measured by an electric dynamometer. The speed is measured by an electrically operated revolution counter and a stop watch.

ticularly attractive. Higher compression pressures hold a promise for them of radiators of smaller area even with motors of increased power. This will be of even greater importance in aviation, where air resistance of the frontal area has a marked effect on performance.

A large number of high compression cars are now on the road. These cars operate without detonation on the Ethyl Gasoline commercially available on every highway in the country, and their performance is far superior to that of cars having the usual average compression.

A manufacturer who desires the increased efficiency of high compression motors but distrusts the available supply of a fuel which will operate without detonation is running from a shadow. There are now over 250,000 pumps in the country that bear the Ethyl emblem. Approximately five million motorists already use Ethyl Gasoline regularly, and the number is growing rapidly.

With the public demanding more power, faster acceleration and favoring low sales prices, the compression pressures of 1932 models seem certain to be higher. And if the present success of cars developing superior performance is an indication, those manufacturers who take best advantage of the compression pressures permissible with Ethyl Gasoline will be rewarded by increased sales. Ethyl Gasoline Corporation, Chrysler Building, New York City.

© E. G. C. 1931

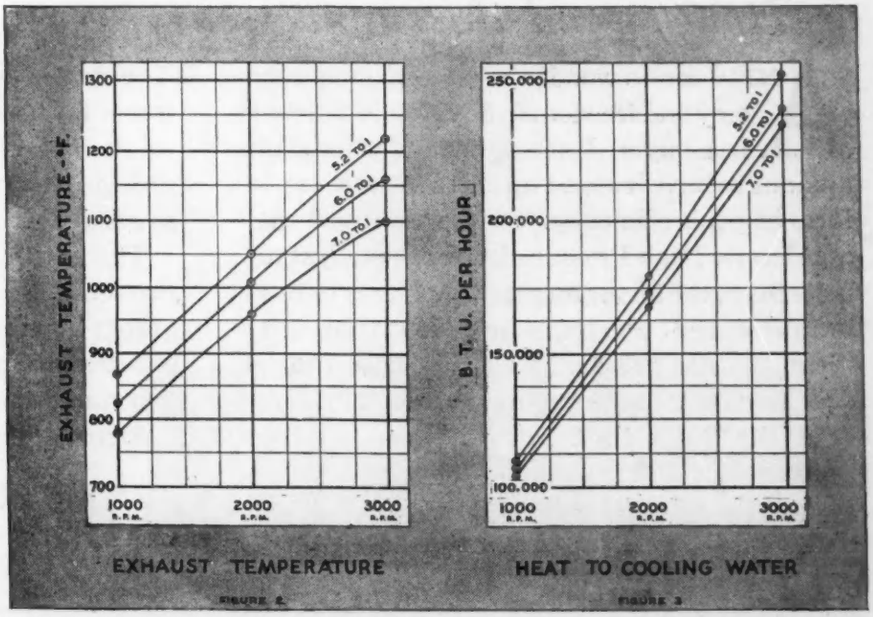
ETHYL GASOLINE

The active ingredient used in Ethyl fluid is lead

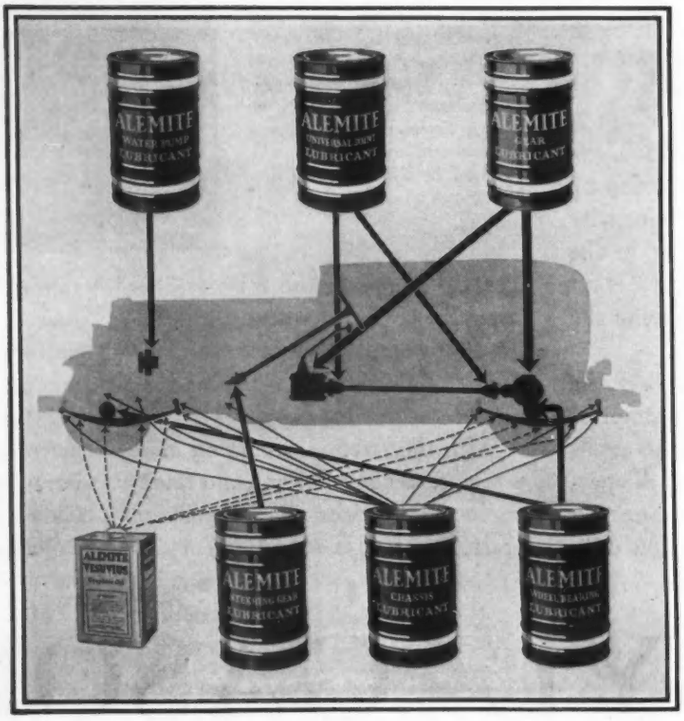
FIGURE 1 shows the relative brake horsepower of the engine (at three ratios of compression) for speeds between 1000 and 3000 r.p.m. Figure 2 shows the temperatures of exhaust gases in degrees Fahrenheit taken by a thermocouple in the exhaust pipe. Figure 3 shows the amount of heat absorbed by cooling water in British Thermal Units per hour.

The Ethyl emblem on any pump stands for tested gasoline of Ethyl quality. Constant inspection of gasoline taken from Ethyl pumps throughout the country guards this standard. Ethyl Gasoline is always colored red.

THE DRIVER OF ANY CAR ANYWHERE IS NEVER FAR FROM ETHYL GASOLINE



Improper, Careless Lubrication Takes Toll From Car Builder, Seller and Buyer



How to end this unnecessary, too-long-tolerated evil

A NEW car—a wonder in performance, economy and freedom from care—is delivered to a buyer. Its designer and builder are anxious to have it stand up and continue to perform at peak efficiency. So it is equipped with an Alemite High Pressure Lubrication System.

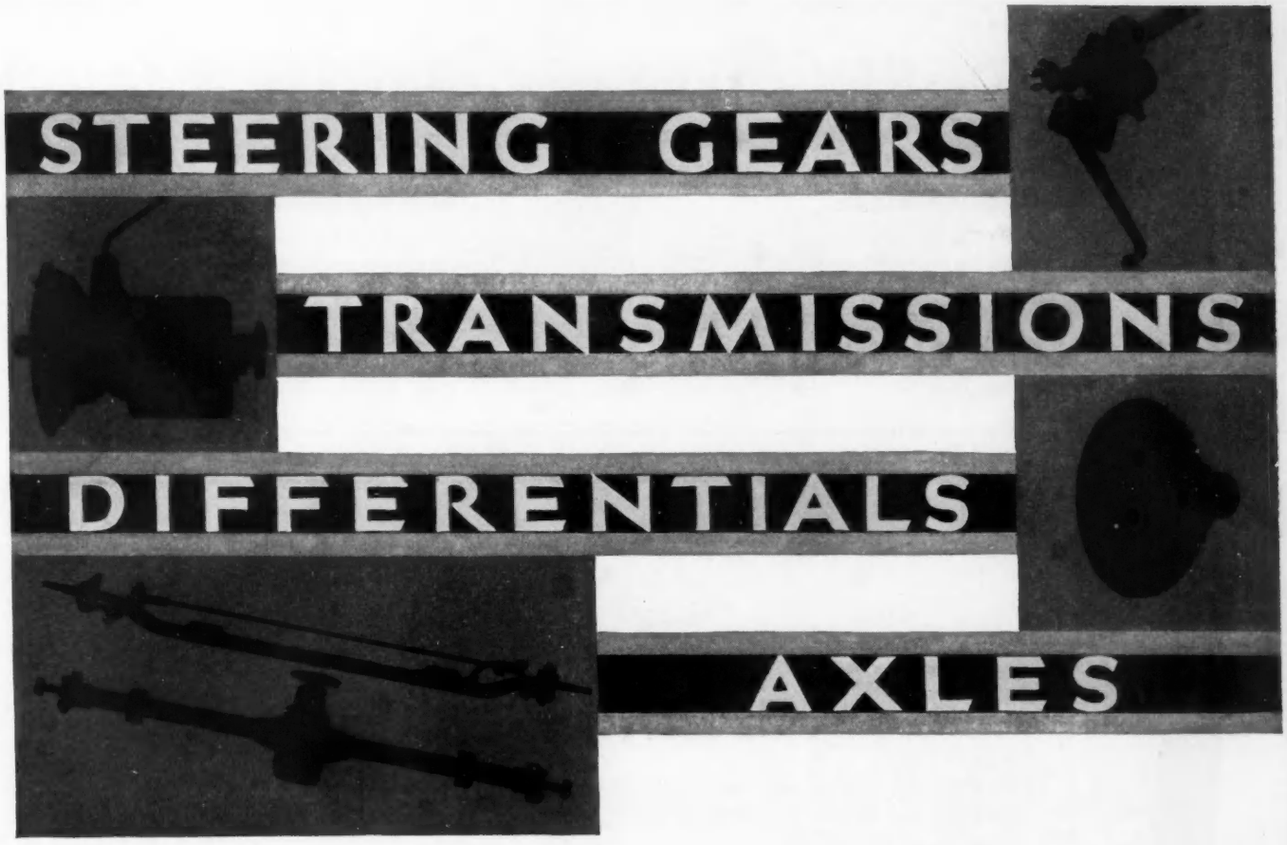
Perhaps the buyer forgets or neglects to have it lubricated. Perhaps he is content with "just any old grease." In either case the result is the same—*premature repairs!* And the bills that follow make a profit for no one. The owner has lost the splendid service engineered into his car. The dealer and the factory have lost the customer for his second, third and even fourth car.

And the unfortunate part of the whole thing is that it was unnecessary—entirely avoidable.

The Alemite Corporation has a definite, *proved* plan for eliminating this evil of improper lubrication. Details will be sent gladly to interested parties on their request. Your inquiry, of course, does not obligate you.

ALEMITE

Alemite Corporation (Division of Stewart-Warner) 2654 North Crawford Avenue, Chicago.



NEW PROCESS GEARS

ESTABLISHED THIRTY-TWO YEARS

NEW PROCESS . . . . is justly proud of its ever growing list of clients. Winning and holding these clients has required outstanding experience in design, engineering, manufacturing, organization, and man-power of exceptional ability. The NEW PROCESS engineering service is in keeping with its product, and is available to all automotive manufacturers.

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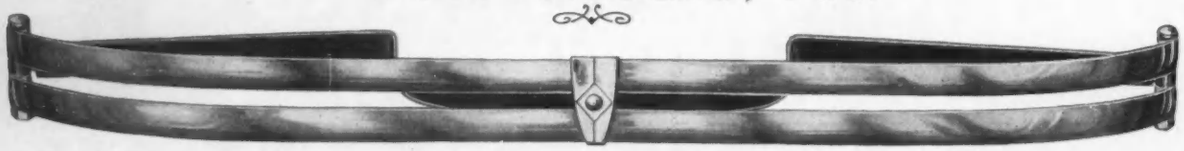
SYRACUSE, NEW YORK

STANDARD STEEL SPRING CO.

CORAOPOLIS, PA.



Springs and Bumpers

BGR INC.

SPRINGS

Chances are even at any rate that you are getting good springs, promptly and dependably, now. If you would like to get better springs, or want a little more prompt delivery, or a more convenient source, tell us about it.

We believe we can be of real service to the engineer on spring design, and our facilities are at your disposal.

We are equipped to make all types of round wire and small flat springs of any material.

«Two Plants for Spring Service»

BGR INC.

DETROIT DIVISION
6400 MILLER AVENUE

COOK SPRING DIV'N
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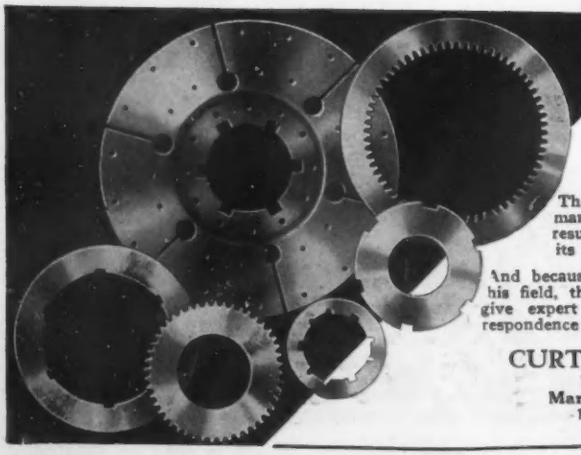


CURTIS CLUTCH DISCS

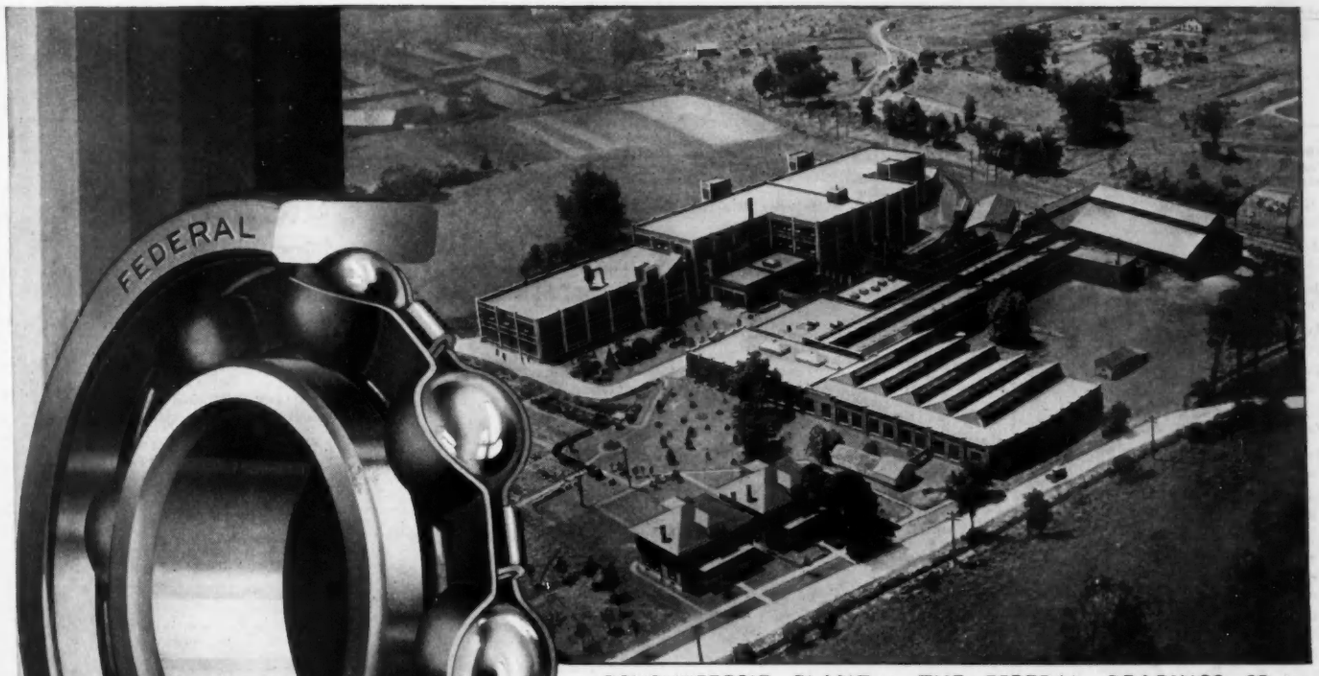
Only long experience in the manufacture of Clutch Discs can tell a manufacturer what is necessary for satisfactory performance in automobile, truck or tractor service.

This company has concentrated its efforts for years on the manufacture of custom-built Clutch Discs of precision. The result of that skilled experience shows in the perfection of its finished product.

And because of solving so many perplexing problems in his field, the Curtis Company is particularly qualified to give expert advice as to your particular needs. Correspondence is invited.

CURTIS CLUTCH DISC CO.
Division of Curtis
Manufacturing Company
1956 Kienlen Ave.
St. Louis, Mo.

CURTIS Cluteh Discs are furnished in high carbon, alloy or mild steel, also non-ferrous metals, plain or slotted, flat or formed, unfinished or ground and polished, tempered or untempered, any size.



POUGHKEEPSIE PLANT · THE FEDERAL BEARINGS CO., *Inc.*

. . . . THE FINEST BALL BEARINGS ARE MADE IN THIS GREAT PLANT. . . .

QUALITY in materials and precision in manufacture . . . . These are the characteristics which distinguish Federal Ball Bearings. The interlocking ball retainer is an *exclusive* feature which adds much to the efficiency of "Federals." For many years, the manufacturers of America's leading cars have selected these bearings because of splendid performance and absolute dependability.

THE FEDERAL BEARINGS COMPANY, INC.
Poughkeepsie, N. Y.

Detroit Sales Office: 917 *Book Bldg.* *Chicago Sales Office:* 120 *N. Peoria St.*

FEDERAL

BALL BEARINGS

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Norma-Hoffmann Bearings Corp.
S K F Industries, Inc.
Strom Bearings Co.

Bearings, Die-Cast
Federal-Mogul Corp.

Bearings, Line Shaft
Link-Belt Co.
S K F Industries, Inc.

Bearings, Roller
Hyatt Roller Bearing Co.
Norma-Hoffmann Bearings Corp.
Rollway Bearing Co., Inc.
S K F Industries, Inc.

Bearings, Roller Radial
Rollway Bearing Co., Inc.
Timken Roller Bearing Co.

Bearings, Roller, Thrust
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Timken Roller Bearng Co.

Bearings, Tapered Roller
Timken Roller Bearing Co.

Blanks, Gear
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Republic Steel Corp.
Wyman-Gordon Co.

Blanks, Sprocket
Akron-Selle Co.

Bodies, Steel
Budd Mfg. Co., E. G.

Bolts
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Boosters, Vacuum Brake
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Brake Drums
Bethlehem Steel Co.
Kelsey-Hayes Wheel Corp.

Brake-Hose Assemblies, Hydraulic
Hydraulic Brake Co.

Brake-Lining
Firestone Tire & Rubber Co.
Multibestos Co.

Brakes, Air
Bendix-Westinghouse Automotive Air Brake Co.
General Electric Co.

Brakes, Hydraulic
Hydraulic Brake Co.

Brakes, Mechanical
Bendix Brake Co.
Kelsey-Hayes Wheel Corp.

Bumpers, Passenger Car
Standard Steel Spring Co.

Bumpers, Truck
Standard Steel Spring Co.

Bushings, Babbitt
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Bushings, Bronze
Federal-Mogul Corp.

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New Jersey Zinc Co.

Camshafts
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Caps, Tank
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Carbureters
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Castings, Aluminum
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Castings, Bronze
Federal-Mogul Corp.

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Meehanite Institute

Castings, Machine Parts
Meehanite Institute

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Clark Equipment Co.
Link-Belt Co.

Castings, Tin Alloy
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Chains, Block
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Morse Chain Co.
Whitney Mfg. Co.

Chains, Roller
Link-Belt Co.
Whitney Mfg. Co.

Chains, Silent
Link-Belt Co.
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Chains, Timing and Automatic Adjustments
Link-Belt Co.

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Pierce Governor Co.

Clamps, Hose
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Clutches, Automotive
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Brown-Lipe Gear Co.
Long Mfg. Co.
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Coils, Ignition
Kingston Products Corp.
United American Bosch Corp.

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Spicer Mfg. Corp.

Couplings, Tubing
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Cranes, Pneumatic
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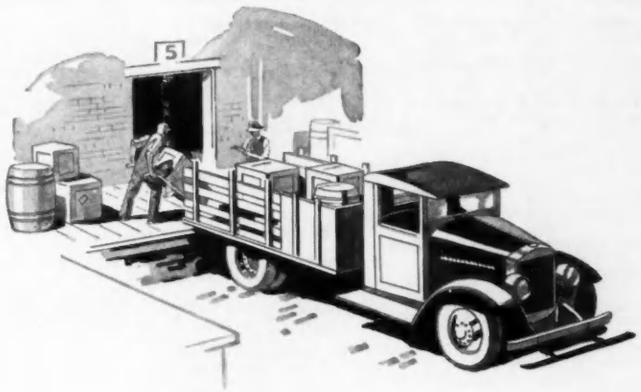
The addresses of companies listed in this index can be obtained from their current advertisements indexed on page 74.



Profit factors

Thousands of trucks, carrying billions of tons of merchandise, depend upon Hydraulic Brakes. Each truck is an important factor in somebody's business. Each must give economical and efficient service.

Lockheed Hydraulic Brakes are an integral part of this service.

Truck manufacturers in ever-increasing numbers are specifying Lockheeds as standard equipment. Reduced assembly costs resulting from minimum time and labor, plus hearty public acceptance of the Hydraulic principle are *profit* factors that cannot be ignored.

HYDRAULIC BRAKE COMPANY
DETROIT, MICHIGAN, U. S. A.

LOCKHEED HYDRAULIC
Four* BRAKES *Wheel

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Meehanite Institute

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Oils, Cleaning
Gulf Refining Co.

Oils, Lubricating
Gulf Refining Co.

Oils, Penetrating
Gulf Refining Co.

Ovens, Electric
General Electric Co.

Packing, Automotive
Garlock Packing Co.

Packing, Water Pumps
Garlock Packing Co.

Panels, Instrument
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Parts, Wood Body
Mengel Co.

Pinions
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Pinions, Starting-Motor
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Pins, Piston
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Aluminum Co. of America

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Pumps, Fuel
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Stewart-Warner Corp.

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Kingston Products Corp.

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Long Mfg. Co.

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Thompson Products, Inc.

Rod, Tie
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Rod, Torque
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Pines Winterfront Co.

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Spark Plugs
A C Spark Plug Co.
United American Bosch Corp.

Speed Reducers
Link-Belt Co.

Speedometers
A C Spark Plug Co.
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Motor Wheel Corp.

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Kelsey-Hayes Wheel Corp.
Motor Wheel Corporation

Spokes, Wood, Passenger Car
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American Steel & Wire Co.
Barnes-Gibson-Raymond, Inc.
Cook Spring Co. Division
Gibson Co., Wm. D.

Springs, Flat
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Barnes-Gibson-Raymond, Inc.
Cook Spring Co. Division
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Bethlehem Steel Co.

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American Steel & Wire Co.
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Bethlehem Steel Co.
Link-Belt Co.
Timken Roller Bearing Co.

Steel, Leaf Spring
Republic Steel Corp.

Steel, Molybdenum
Republic Steel Corp.

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A NATION-WIDE NETWORK OF SERVICE STATIONS

From coast to coast, from the Great Lakes to the Gulf of Mexico, in metropolitan centers, and in tiny cross-roads hamlets, are to be found the signs of official Auto-Lite Service Stations. The owner of the Auto-Lite equipped car—more than half the automobiles built today are Auto-Lite equipped—never finds himself far from a place where the electrical system may be serviced.

This is one of the reasons for the popularity of Auto-Lite electrical equipment with car owners. Another reason is Auto-Lite's well-known policy of building only the finest quality and workmanship into starting, lighting and ignition systems. Car owners naturally prefer, and insist upon, Auto-Lite dependability.

THE ELECTRIC AUTO-LITE COMPANY, TOLEDO, OHIO

Auto-Lite

Starting, Lighting & Ignition

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Bethlehem Steel Co.
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Steel, Special Analysis
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Steel, Tool
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Timken Roller Bearing Co.

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Steel, Turned and Polished
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Tanks, Vacuum
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Wilcox-Rich Corporation

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Tubing, Flexible Metal
Chicago Tubing & Braiding Co.
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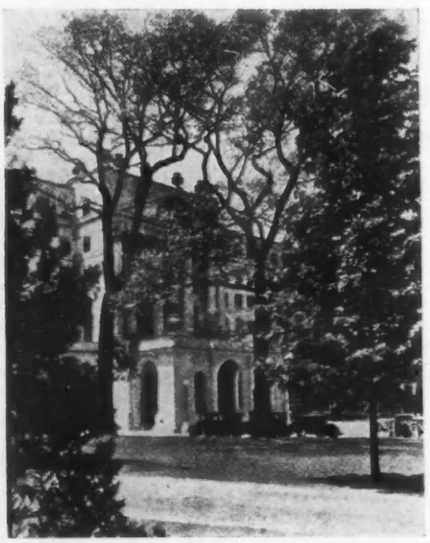
Zinc, Slab
New Jersey Zinc Co.

Zinc, Stick
New Jersey Zinc Co.

Zinc, Strip
New Jersey Zinc Co.



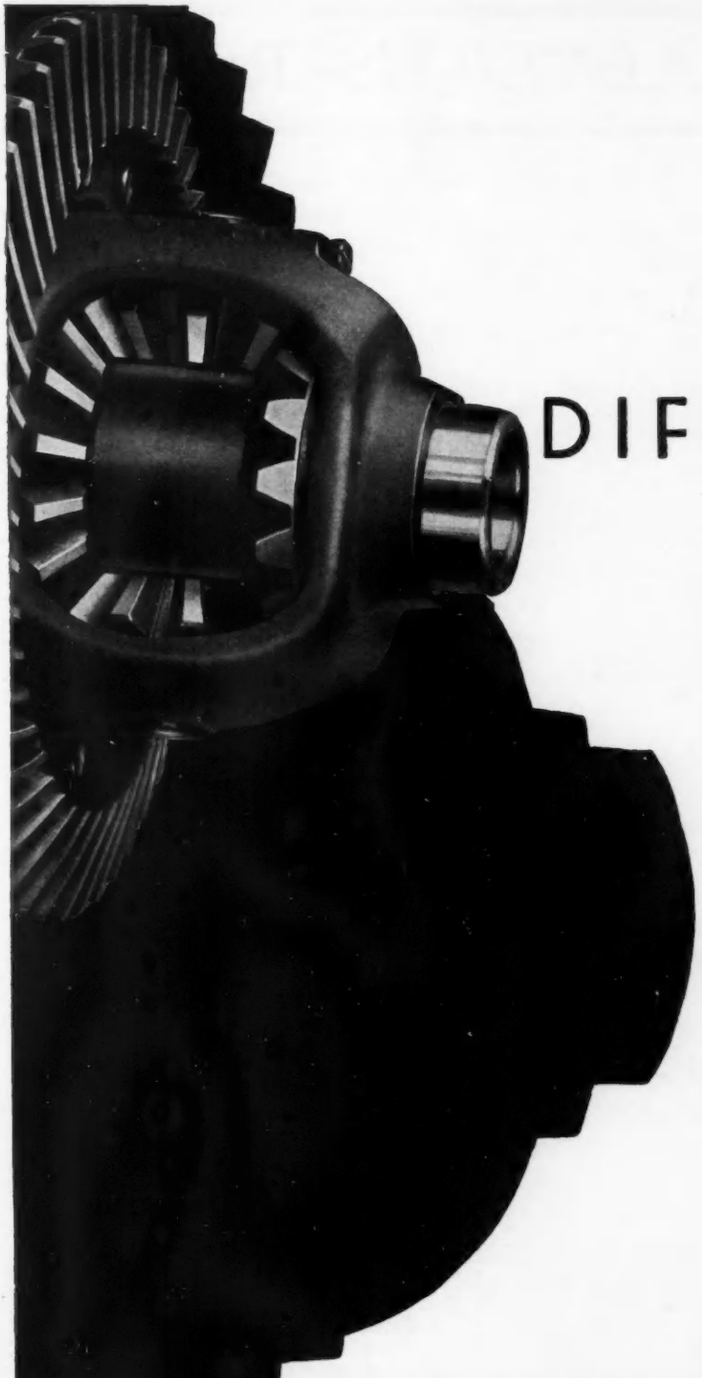
1931 S. A. E. Summer Meeting

JUNE 14-19, 1931

WHITE SULPHUR SPRINGS
WEST VIRGINIA

Last Call for Reservations

Read over the detailed program printed in this issue and you will realize why you can't afford to miss such an outstanding meeting.



DIFFERENTIALS

BEVEL DRIVE GEARS

The reason Brown-Lipe-Chapin differentials and gears so perfectly meet today's rear-end requirements is that they are the rational development of a design that time and experience have taught us to be fundamentally correct.

MANUFACTURED • AT SYRACUSE • NEW YORK

BROWN LIPE CHAPIN

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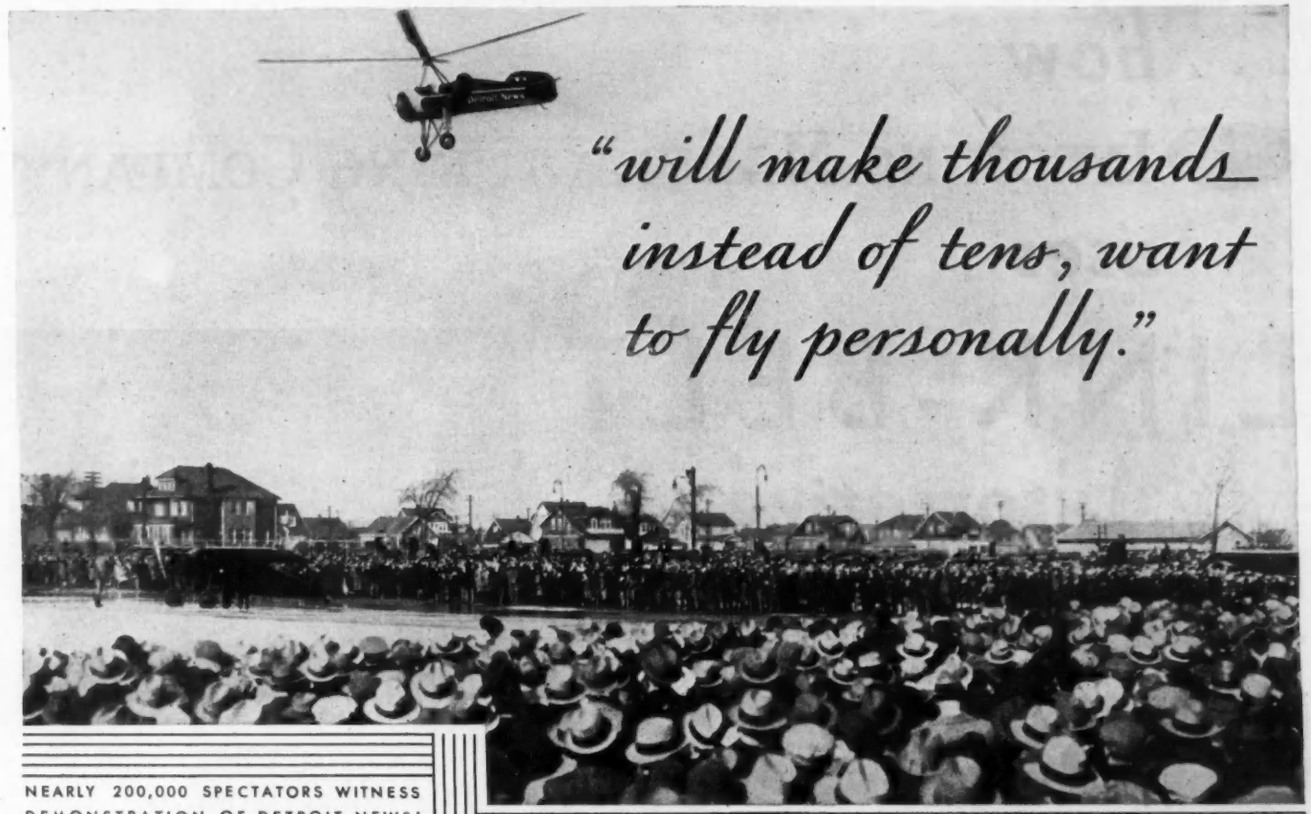

NEARLY 200,000 SPECTATORS WITNESS DEMONSTRATION OF DETROIT NEWS' AUTOGIRO, FEBRUARY 15, 1931

Characteristics

The Autogiro differs basically from all other heavier-than-air craft in the source of its lifting capacity. This lift is given primarily by four rotating blades which take the place of the familiar wings of an airplane. There is no time when this supporting rotation of the blades can be stopped while the machine is in the air, as their motion is produced solely by wind pressure caused by the movement of the Autogiro in any direction, climbing, level flight, gliding or descending vertically. The supporting rotation of the blades is entirely independent of the engine, whose sole function is to propel the Autogiro.

The Autogiro presents flying characteristics hitherto impossible. It can take off at low speed after a very short run, and immediately assume a steep-climbing angle. It can fly well over 100 miles per hour or as slowly as 25 miles per hour. It can be brought momentarily to a standstill and hover. It can bank and turn slowly without fear of loss of forward speed. It can glide or descend vertically at a speed less than that of a man descending in a parachute, and with virtually no forward speed even with a dead engine. Above all, it cannot fall off into a spin from a stall. As a result, little operating skill is required.

"*THE accomplishment that will put individual flying on the same basis of universality as the auto will be a flying machine that is as nearly fool-proof as the auto. The learner won't have to spend four or five hundred dollars learning to fly it, and he won't have to drive it through the air at better than express train speed in order to secure sustentation and control. He can climb it out of an airport half the size of a city block and land it in the same. And if the motor stalls, he won't have to say his prayers.*"*

"*A relatively small proportion of the present industry will suffice to supply all the needs of a normally expanding air transport activity and take care of military demands. The big business must come from the individual buyer.*"*

The Autogiro was conceived and developed especially to meet the requirements of the private owner market. A study of its characteristics reveals how completely its purpose has been accomplished.

The Autogiro Company of America is not a manufacturing or selling company. It is solely an engineering and licensing organization. It owns and controls, exclusively, all Autogiro patent rights in the United States. Manufacturing companies of high standing will be licensed to build Autogiros with the full cooperation of our engineering staff . . . Present licensees are: Buhl Aircraft Company, Detroit, Mich. . . . Kellett Aircraft Corp., Philadelphia, Pa. . . . Pitcairn Aircraft, Inc., Willow Grove, Pa. . . . We are now prepared to arrange demonstrations to acquaint the industry with Autogiro principle, design and operation, and to discuss production privileges.

* *Italicized statements quoted from recognized authorities; names on request.*

AUTOGIRO COMPANY OF AMERICA · · · LAND TITLE BUILDING · · · PHILADELPHIA

AUTOGIRO

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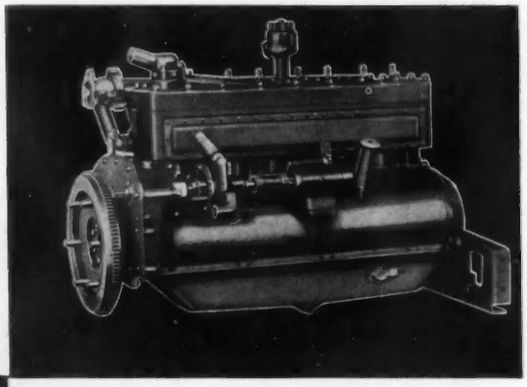
. . . how

POWERED BY LYCOMING

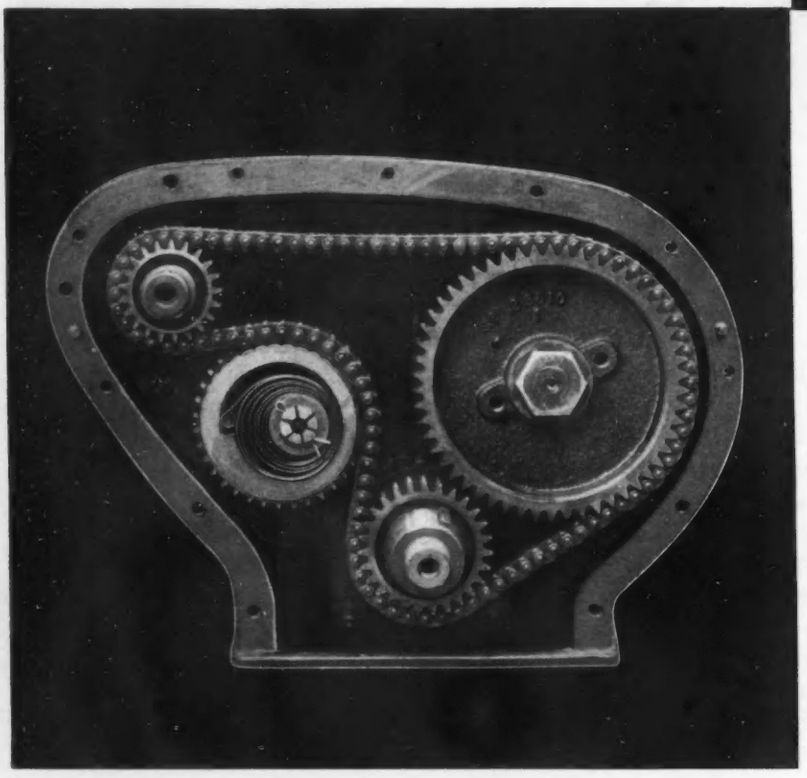
LYCOMING MANUFACTURING COMPANY

uses

LINK-BELT Automotive SILENT CHAIN



Model "FFA" Lycoming Engine used in Cord cars.



Link-Belt Automotive Silent Chain, with automatic adjustment, as used in the model "FFA" engine.

LYCOMING Manufacturing Company, builders of quality gasoline automotive engines, have since 1924 used Link-Belt Automotive Silent Chain. For seven years they have assured the users of their engines reliable, satisfactory timing.

During this interval, they have used two-wheel or three-wheel drives, and manual or automatic adjustment as needed, each drive being designed for a specific operating condition. Link-Belt Automotive Silent Chain is built by the leading manufacturers of positive power transmission equipment, and by an organization that has served and grown with the automotive industry since timing chains were first used.

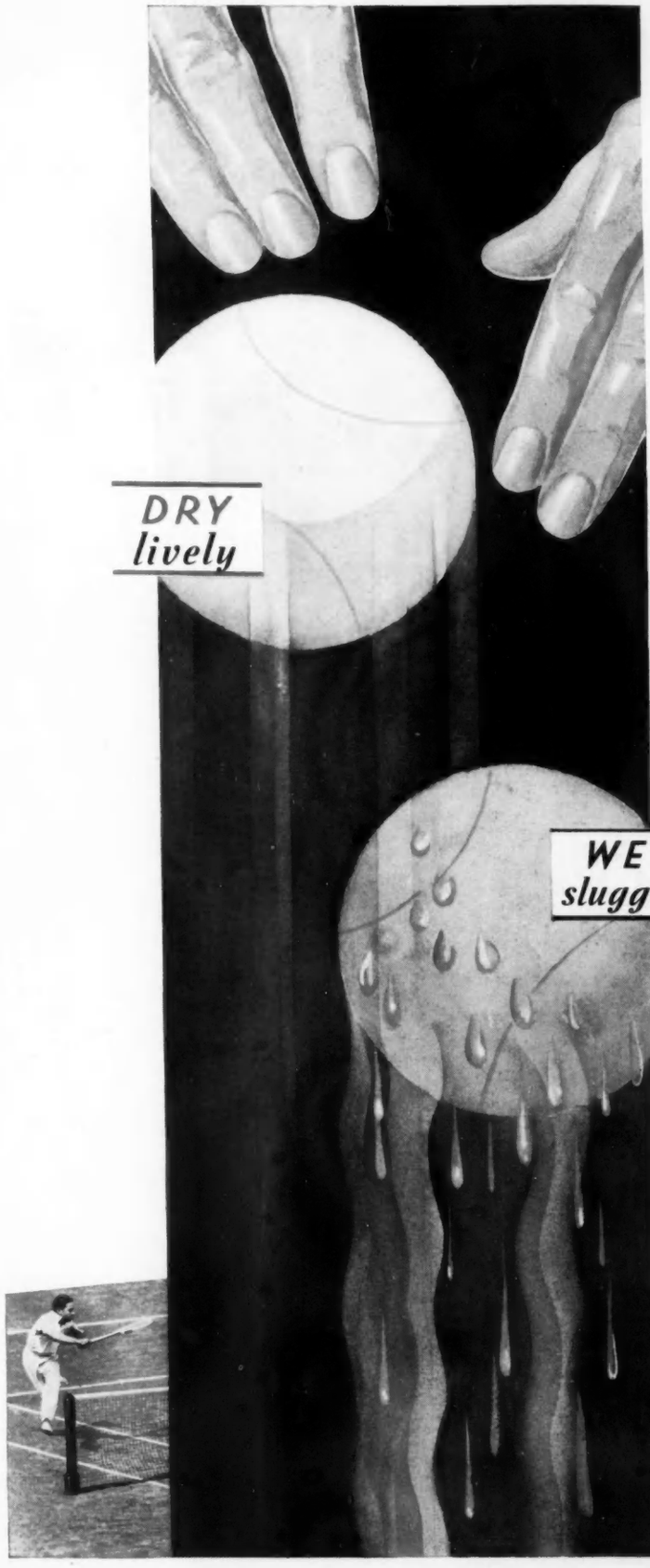
Our engineers are at your service.

LINK-BELT COMPANY
INDIANAPOLIS - - DETROIT

LINK-BELT

MANUAL ADJUSTMENT SILENT AUTOMATIC ADJUSTMENT

4317



for speed on the court
A DRY BALL

for speed on the road
A DRY GAS

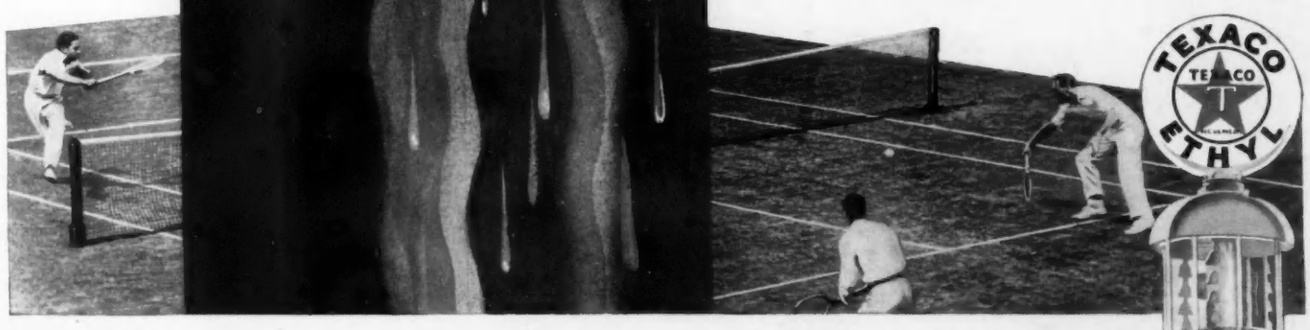
Just as the spectacular playing of a tennis star may be marred by a wet, sluggish ball, so the sparkling performance of even the finest car may be impaired by wet gas.

Texaco-Ethyl is the "dry" Ethyl gasoline. It is dry as it leaves the manifold—dry as it enters the cylinders—completely responsive to every spark flash.

There are no fuel-starved cylinders to impair the performance of the engine, for Texaco-Ethyl serves each with a uniform mixture of dry, live gas and smooth, anti-knock material. No coughing, sputtering starts, no stalling in traffic.

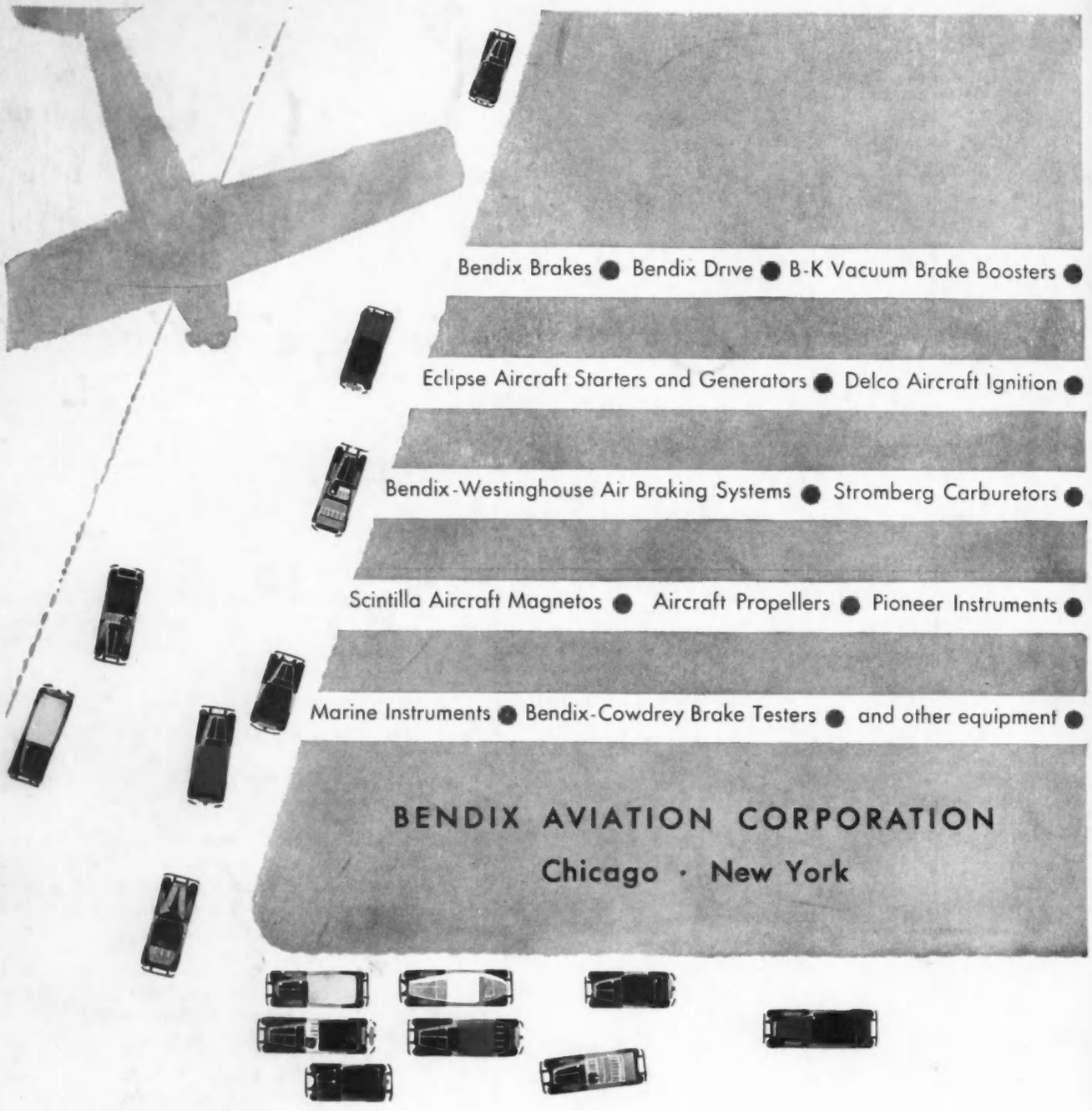
Texaco-Ethyl Gasoline, the new and better Texaco Gasoline, both dry, and the new "crack-proof" Texaco Motor Oil are sold in all our 48 States.

THE TEXAS COMPANY
135 East 42nd St., New York City



TEXACO–ETHYL

THE "DRY" ETHYL GASOLINE



Bendix Brakes ● Bendix Drive ● B-K Vacuum Brake Boosters ●

Eclipse Aircraft Starters and Generators ● Delco Aircraft Ignition ●

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Marine Instruments ● Bendix-Cowdrey Brake Testers ● and other equipment ●

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